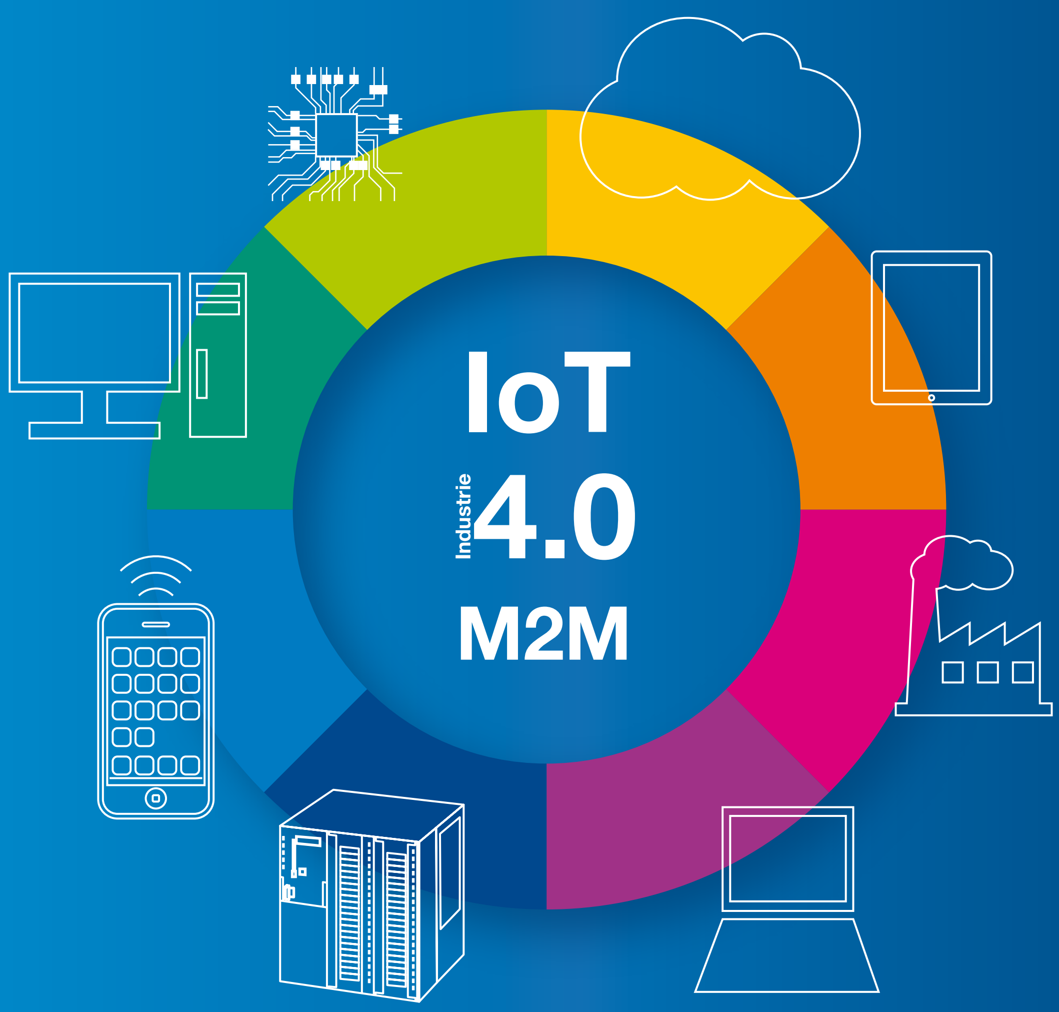
OPC Unified Architecture

Interoperability for Industrie 4.0 and the Internet of Things

OPC UA



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 the smart world of connected systems.

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 industry and also becoming more popular in other markets like the Internet of Things (IoT). With the introduction of Service-Oriented-Architecture (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 IoT, M2M (Machine to Machine) and Industrie 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 OPC-UA to be a key ingredient of data and information exchange standards.

Regards,
Thomas J. Burke
President and Executive Director
OPC Foundation
thomas.burke@opcfoundation.org
www.opcfoundation.org

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OPC-UA: Industrial Interoperability for IoT

Digitalization is an important and very attractive growth market. The goal is to foster the integration of IT Technologies with products, systems, solutions and services across the complete value chain stretching from design to the production to maintenance. Additionally new business opportunities will arise like the digitalization of products and systems, new and enhanced software solutions and new digital services.

IoT defines a series of technologies that have traditionally not been connected and will now be connected to an IP-based network. These technologies are the most important drivers of the digital growth. In the center of the standardization is the so called "Machine-to-Machine" (M2M) communication. Many companies and associations like the OPC Foundation with OPC-UA have been engaged in these standardization efforts for many years.

MACHINE INTERACTION

M2M typically defines the communication between two machines or the data transfer between a more or less intelligent device and a central computer. The communication media is either a cable modem or wireless modem. In more modern devices – in example a vending machine – the communication was using the cell-network and a SIM card was placed in each machine. It then communicated directly via a point-to-point connection with the dedicated computer to send sensor data – for example the fill-level – and other alarm messages to the machine owner. The business models resulting from this are mainly around logistics and maintenance as well as special condition monitoring and preventive maintenance. For example in the industrial environment, airplane turbines are sent to the airports and constantly monitored to send replacement parts in time to reduce the maintenance times.

INTERNET

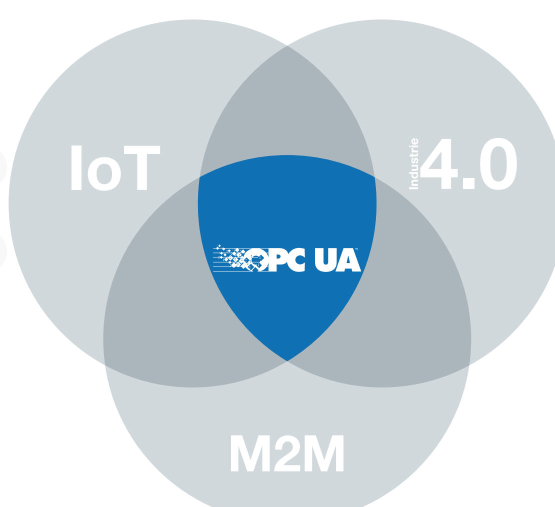
At the base, the internet of things requires remote device access as well. Therefore M2M is a part of the IoT but is not limited to the exchange of data between intelligent devices. It also includes data from simple sensors and actors (i.e wearables for fitness solutions in the consumer space) that will be first aggregated and processed locally then sent via gateways (a smart phone) to central systems in the cloud. Within IoT very complex networks of intelligent systems are emerging. A similar development can be observed for industrial solutions: Machines and field devices are not just connected to networks and send data. They additionally can process and combine data from other devices due to the increasing computing power of these devices. They can consume and provide information from and to other field devices to create new value for the user. In the end a machine can, by itself, provide a maintenance strategy for the technicians or deliver information about the history of maintenance – instead of just providing data of the oil-pressure and temperature.

COMMUNICATION

The requirement for the communication of things and services inside the IoT is vastly different than today's established structures: The IoT communication with devices will rarely happen directly. Sensor and device information will be published and consumer can subscribe to this information (Publish/Subscribe). Typically these things and systems will communicate via IP-Networks between each other and with cloud based big-data applications. The customer benefits are created by the combination of these intelligent devices and systems with services that operators provide to their customers.

OPC-UA INTEROPERABILITY

The vision of IoT can only be realized, if the communication of the central components is based on a global communication standard that can fulfill the complex requirements. Additionally to a publish/subscribe model for the low-resource, one-to-many communication paradigm a secure connection oriented client/server communication model is required to handle the bi-directional communication that allows sending control commands to actors. Furthermore information must be accompanied by a semantic meta-model that describes the data and its purpose to guarantee the best usage of the data. The aggregation of information on many layers adds additional meta-data and therefore it is of critical importance to use a single standard. Scalability and the possibility of integration across all layers is required as well as platform and vendor independence. OPC-UA offers a complete solution for all requirements on all vertical layers for remote device access.



Remote Device Access (with OPC-UA) as the common intersection of M2M, IoT and Industrie 4.0

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

CHALLENGE

In order to maintain the competitiveness of modern industrial countries 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 (Industrie 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.

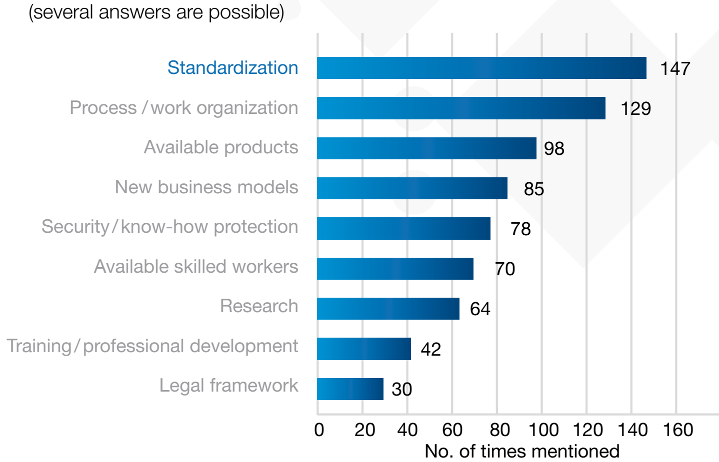
REQUESTS

Considerable effort is required for implementing the vision of Industrie 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 Industrie 4.0.

Source: Forschungsunion, acatech 2013

CHALLENGES FOR THE IMPLEMENTATION OF INDUSTRIE 4.0

(several answers are possible)



Result of the survey from the members of BITKOM, VDMA and ZVEI regarded standardization as the biggest challenge in the implementation of Industrie 4.0.

Source: “Recommendations for implementing the strategic initiative Industrie 4.0”, Forschungsunion, acatech 2013

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 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. Projects have already been successfully realized in Amazon and Microsoft Azure Cloud.
Secure transfer and authentication at user and application level	OPC-UA uses X.509 certificates, Kerberos or user/password for authentication of the application. Signed and encrypted transfer, as well as a rights concept at data point level with audit functionality is available in the stack.
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 two protocol bindings are available: optimized TCP-based binary protocol for high-performance applications and HTTP/HTTPS web service with binary or XML coded messages. Additionally Publish/Subscribe communication model can be integrated. The stacks guarantee consistent transport of all data. Besides live and real time data also historical data and their mathematical aggregation are standardized in OPC-UA. Furthermore method calls with complex arguments are possible, but also alarm and eventing via 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 concept for an object oriented address space (not only hierarchical but full-meshed network), including metadata and 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. 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 located local (on the same host), in a subnet or global (within enterprise). 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, AIM, 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.
Verification 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). Additionally various validations regarding data security and functional safety are performed by external test and certification bodies.

»OPC-UA plays a critical role in opening up new opportunities across manufacturing as data from connected products, devices, and sensors increasingly becomes the fuel for insights, productivity , and new business models in an IoT world. In keeping with our commitment to openness and collaboration, Microsoft is fully committed to supporting OPC-UA and its evolution in a rapidly transforming OT/IT landscape.«

Rohit Bhargava, CTO, WW Manufacturing & Resources, Microsoft Corporation

»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.«

Veronika Schmid-Lutz, Chief Product Owner Manufacturing, SAP AG, OPC board member

OPC-UA in the IT world

»Oracle has long recognized the value of strong data and communications standards to develop secure and extensible, platform-independent solutions that help grow markets and businesses. We see Oracle Java and OPC-UA as a powerful combination for developers seeking to integrate systems in a secure, extensible, platform-independent manner. From embedded systems to the cloud, the Oracle Java platform provides a common, uniform programming environment which, when coupled with the OPC-UA information model, offers strong flexibility, ease of integration, and strong security.«

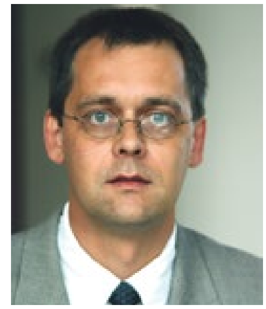
Scott Armour, VP Global Java Business Unit, Oracle

»Networking of machines, products, their components and digital services as described in the context of Industrie 4.0 and the Internet of Things (IoT) make great demands on future protocols and standards. Those have to support “plug & play” scenarios, which enable the dynamic integration into value chains and networks. Therefore components need the capability to provide the description of their functions and features by themselves. OPC-UA as standard already today provides the secure exchange of data and the semantics for describing functionalities. By this OPC-UA comes with an essential capacity, which easily can be enhanced to move forward with Industrie 4.0 scenarios. Platform independence corresponds to HP’s open stack approach.«

Johannes Diemer, Manager Industrie 4.0, Hewlett-Packard GmbH

»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



»ABB is offering a classic OPC interface for most of its products or uses classic OPC to integrate data. As OPC-UA does not only allow data exchange but provides information modeling capabilities and communication in a secure, platform-independent way we see a high potential and are fully committed to it. Our customers will benefit from reduced integration efforts and new application scenarios by utilizing the possibilities of OPC-UA.«

Thoralf Schulz, Global Technology Manager for Control Technologies, ABB

OPC-UA in the industry

»OPC DA is the most popular and successful standard interface on the automation systems. Yokogawa joins OPC Foundation from the beginning and has much contributed to the development of OPC interface. Now Yokogawa is fully committed itself to new promising OPC-UA and will contribute to the development as ever.«

Nobuaki Konishi, 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 and manufacturer-independent communication standard is offered to the industry. Its scalability allows horizontal and vertical networking of systems, machines and processes. Bosch Rexroth consistently uses this internationally accepted open standard as a key technology and offers extensive services and semantic information models for its products. We develop the functionality continuously, so that our customers are able to ideally integrate Rexroth products in their automation environment – for the optimal implementation of Industrie 4.0.«

Dr. Thomas Bürger, Vice President Engineering Automation Systems, Bosch Rexroth AG

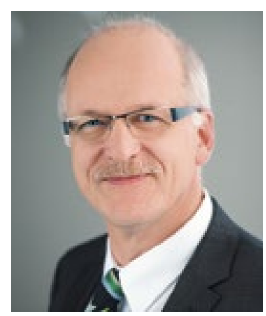
»OPC-UA has the potential for an immediate cross-vendor implementation of Industrie 4.0 and the necessary internet based services.
The adoption of this open standard is an opportunity for vendors and users. Proprietary solutions will not generate an adequate value.«

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 a global technology powerhouse and the world market leader in the area of automation systems. We‘re seeing digitalization of all sectors of industry and we‘re playing an active role in shaping it.
As a founder member of the OPC Foundation, Siemens is keen to drive the development of automation and optimize the interoperability of technologies from different system providers. And this commitment is already bearing fruit: OPC standards are used in many of our innovations, such as the Sinema Server network management solution, the Simatic HMI (Human Machine Interface) and the flexible, modular Simocode pro motor management system. OPC-UA is an implementation that we regard as particularly relevant and key element for Industrie 4.0. 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

»Schneider Electric sees the advent of the Industrial Internet of Things as an “evolution”, not a “revolution”. In a world where our smart connected products and systems operate as part of larger systems of systems, consistency when moving data is important. Even more important is putting data into context. With OPC-UA we can efficiently and effectively deliver systems and applications that do just that – and thus help our customers fully realize the potential of Industrie 4.0.«

John Conway, VP Strategy & Partnerships, Schneider Electric

»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 proves to be ideal for implementing the functionality required for Industrie 4.0, in terms of communication within automation systems, and interoperability between Industrie 4.0 components via defined objects and semantics. Due to the international support of different automation solution providers, the protocol already finds a use in numerous devices, from the sensor level to Manufacturing Execution Systems (MES) to Enterprise Resource Planning systems (ERP). Acceptance and a future-oriented technological basis will result in the development of an international and evolving standard – OPC-UA provides this basis.

Roland Bent, Managing Director, Phoenix Contact

»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.«

John Kowal, Board member OMAC & PMMI
(B&R Industrial Automation Corp)

»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

»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.«

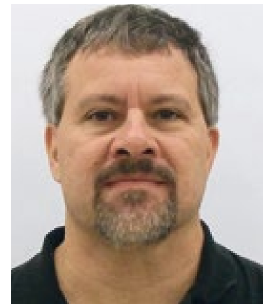
Prof. Dr.- Ing. habil. Arndt Lüder, Otto-v.-Guericke University Magdeburg, Fakulty Mechanical Engineering, AutomationML e.V. Board of Directors

»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.«

Wolf-Rüdiger Hansen, 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: 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 offers a secure, reliable, interoperable and platform-independent basis for the MDIS information model. The simplified communication connections and increasing data quality offer the oil & gas operators a real value-add."

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

Thought Leaders from R&D and Science

»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 inoperability.«

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

»A key component for the realization of the Industrie 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)

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 latest technology generation from the OPC Foundation for the secure, reliable and vendor-independent transport of raw data and pre-processed information from sensor and field level up to the control system and into 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. Additional protocol bindings like Multicast or Message-Queuing can be integrated easily without breaking exsiting communication concepts. The integrated encryption mechanisms ensure secure communication over the Internet.

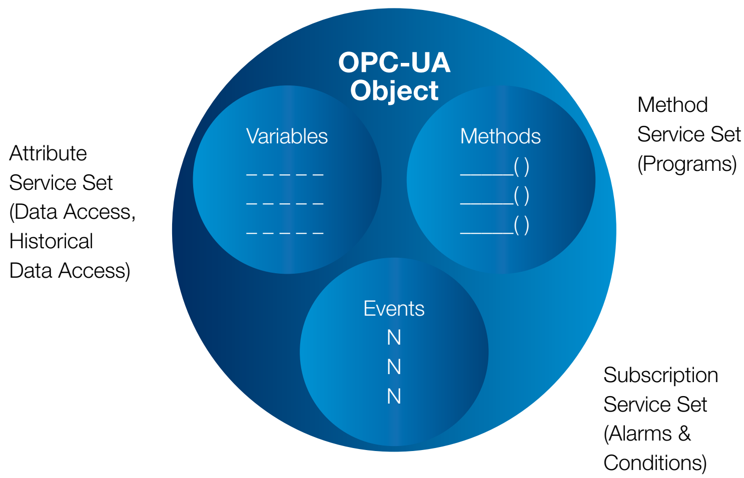
SERVICE-ORIENTED ARCHITECTURE

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 from 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, 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

Uniform OPC-UA object



also used for secure communication in the Internet, such as SSL, TLS and AES. The safety mechanisms 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 UNIFICATION

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 allows 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 organizations 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, AIM, BACnet, ISA and FDI. Additional specifications are compiled that contain common, semantic definitions of information models.

OPC-UA technology in detail

Karl-Heinz Deiretsbacher,
Technology&Innovation,
Siemens AG
Director of the OPC-UA Technical
Advisory Board
SIEMENS

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

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.

DESIGN OBJECTIVES

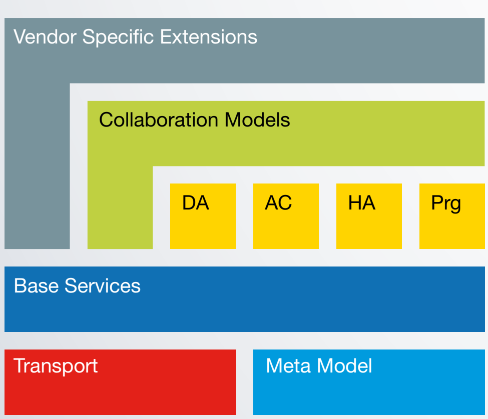
OPC-UA was designed to support a wide range of systems, ranging from PLC's in production to enterprise servers. These systems are characterized by their diversity in terms of size, performance, platforms and functional capabilities.

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

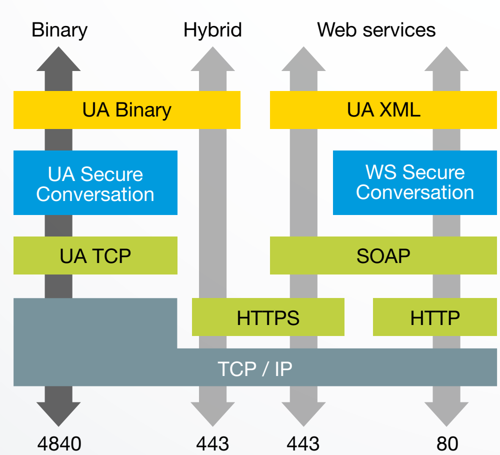
- → Transport – for the data exchange mechanisms between OPC-UA applications. Different transport protocols exist for different requirements (optimized for speed and throughput = UA TCP with UA Binary; firewall-friendly = HTTP + Soap).
- → Meta model – specifies the rules and basic components for publishing 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

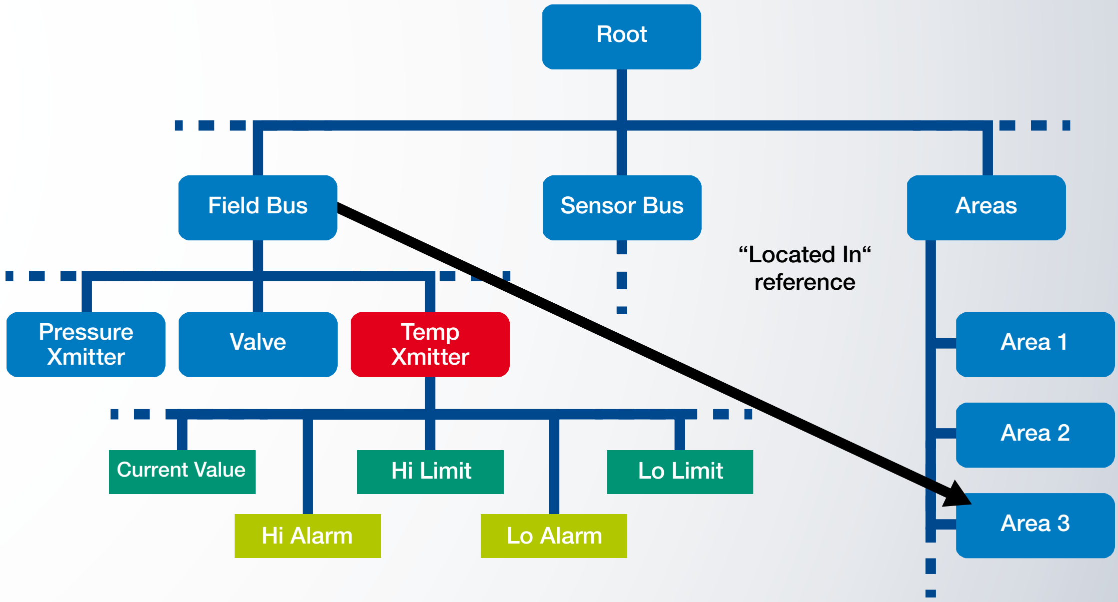
INTEGRATED ADDRESS SPACE MODEL

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 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 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.

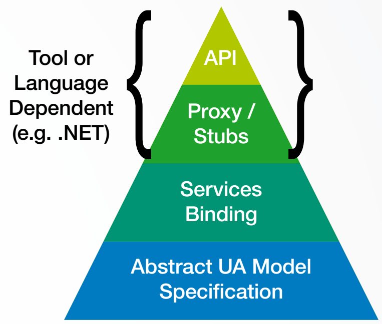
→ **MonitoredItem service set**
This service can be used to determine which attributes from the address space should be monitored for changes by a client, or which events the client is interested in.

→ **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 real-time data, i.e. data that represent current state and behaviour 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)

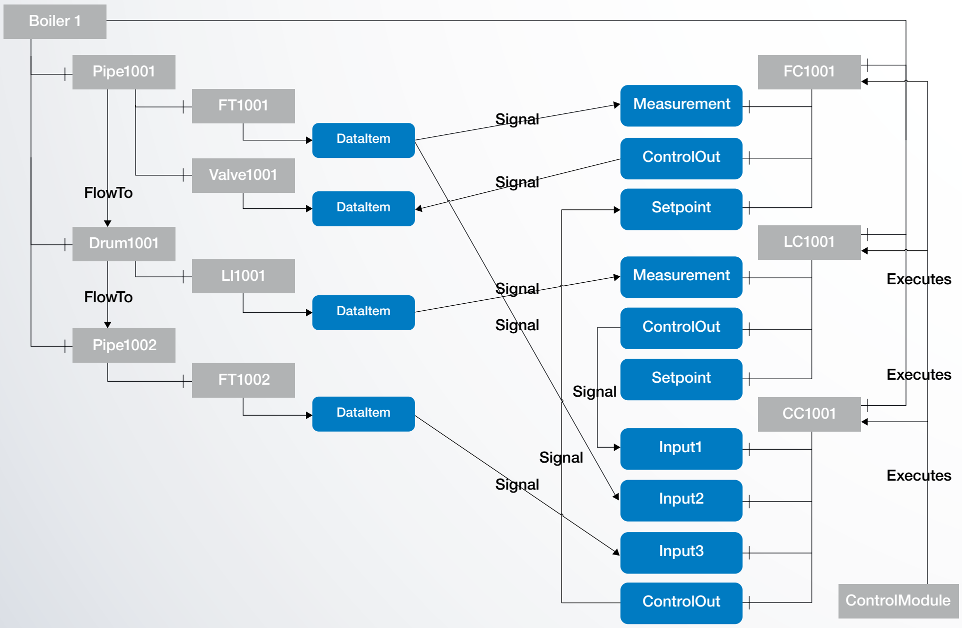
This information model defines how states (dialogs, alarms) are handled. A change of state triggers an event. Clients can register for such events and select which of the available associated values they want to receive as part of the event report (e.g. message text, acknowledgment behavior).

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.



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)
- → OPC-UA for AutoID (AIM)
- → OPC-UA for BACnet (Building Automation)

INDUSTRIE 4.0: OUTLOOK

OPC-UA is a mature standard, which meets the requirements of Industrie 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?

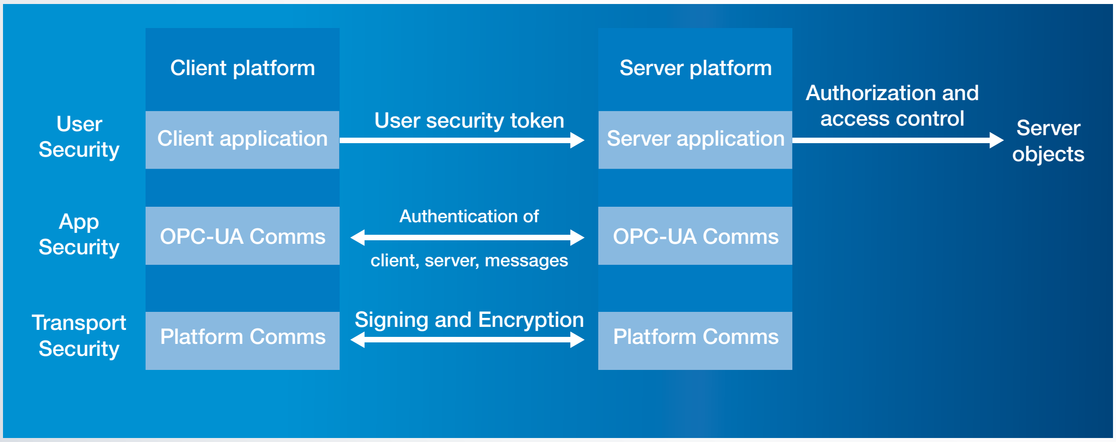
SECURITY MODEL

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

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).



Scalable security concept

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.

Security check by German Federal Office for Information Security

Holger Junker, German Federal Office for Information Security, (BSI), head of Division C12

OPC-UA is one of the most important modern standards for industrial facilities and many further scenarios in an intelligent and connected world. OPC-UA is considered a central building block on the way towards Industrie 4.0. It enables integration between various layers of the automation pyramid from sensor up to the ERP system. It is the first time a unified, worldwide recognized industrial protocol can be employed that allocates necessary cryptographic mechanisms for a secure smart factory.
In order to further raise trust in OPC-UA, BSI currently conducts a comprehensive and independent security check.

In the first step the OPC-UA specification will be thoroughly analyzed. Next a chosen reference implementation will be tested concerning security. The goal of the project is to issue a detailed, meaningful analysis of OPC-UA, proposals for possible necessary improvements as well as recommendations for equipment producers, integrators and manufacturers. The OPC Foundation supports BSI in their security check effort. The results will first be discussed with the OPC Foundation towards the end of 2015. Next, an official release of the elementary results together with resulting recommendations will be published.

»The only communication technology in the factory, with implicit security features and the potential for the challenges posed by Industrie 4.0, that I am aware of today, is OPC-UA.«
Holger Junker, BSI

Extending the communication methods

The OPC-UA working group is currently integrating additional communication methods into the OPC-UA standard. They will extend the Client-Server architecture with the well-known Publish/Subscriber model where the Server (Publisher) can publish its data to an arbitrary number of Clients (Subscribers). This will improve the usability of OPC-UA in application fields like M2M (Machine to Machine) and IoT (Internet of Things).

TWO DIFFEREN METHODS WILL BE AVAILABLE TO SUPPORT DIFFERENT SCENARIOS:

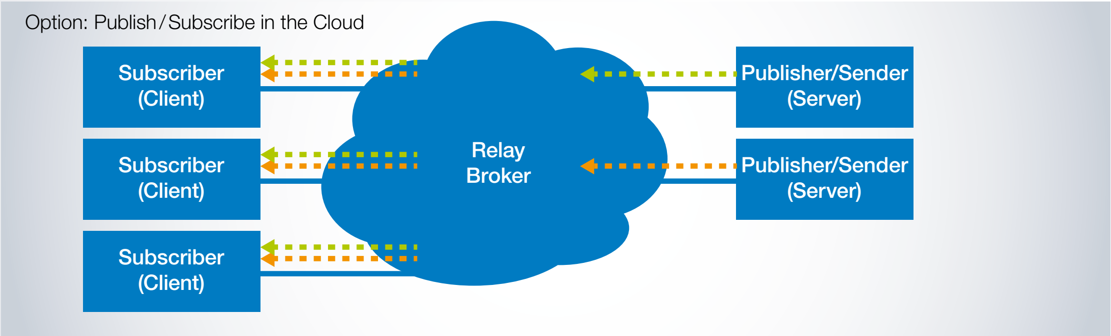
→ 1. Publisher/Subscriber over fast, local communication media

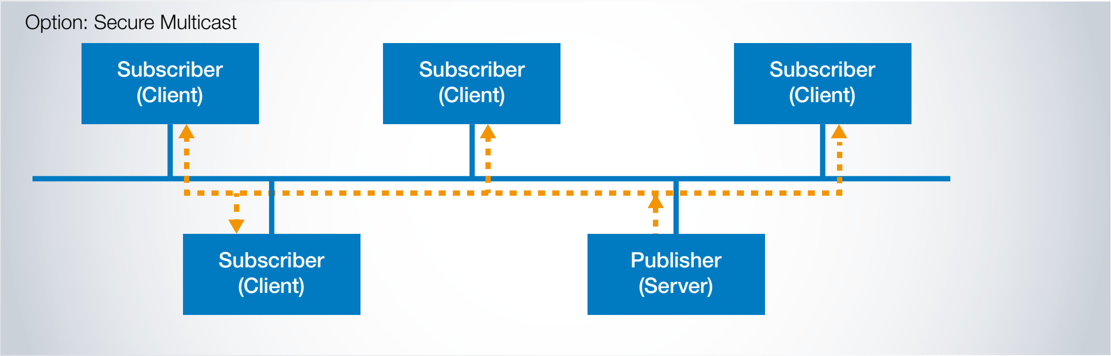
This method is targeted to local networks. The data will be sent once (published) and received by any number of Clients (Subscribers) using UDP Secure Multicast. It allows extremely efficient data distribution without brokerage.

→ 2. Publisher/Subscriber for message exchange in global networks (Cloud)

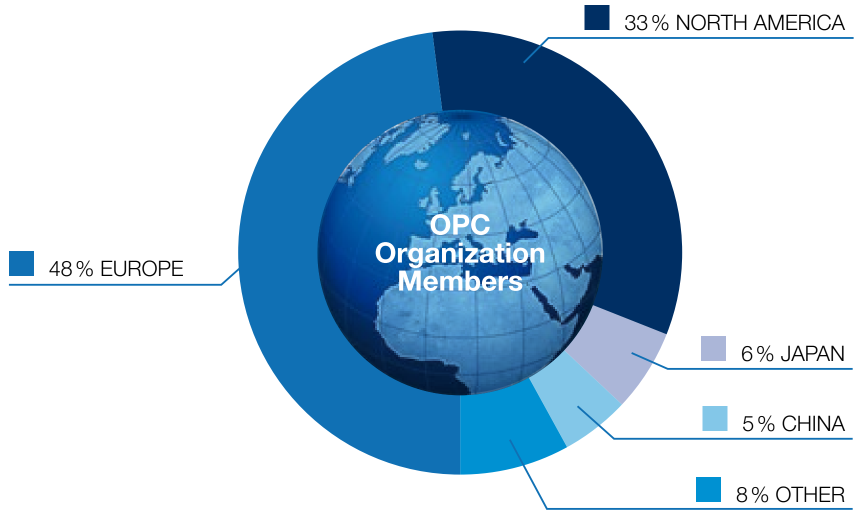
This model supports connectivity between OPC-UA applications that reside in different networks, or where data shall be published to Clients that reside “in the Cloud”, as well as network topologies where relays, brokers, or event hubs enable the data transmission. It can connect any number of Servers with any number of Clients.

Both additions integrate seamlessly into the multilayer architecture of OPC-UA where extensibility is part of the design. Just like the already existing Client-Server communication methods, the new Publish-Subscribe methods for OPC-UA will utilize well-established protocols. For Secure Multicast, for example, the focus is on the User Datagram Protocol (UDP) and Time Sensitive Networking (TSN). For Publish/Subscribe in global networks, the working group focusses on the Advanced Message Queuing Protocol (AMQP). Both additions also only apply to the transport of data, not the information model of the application. I.e., the application and the information that it exposes does not need to be changed.





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 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 for exchange of information and networking. Three times each year, 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.

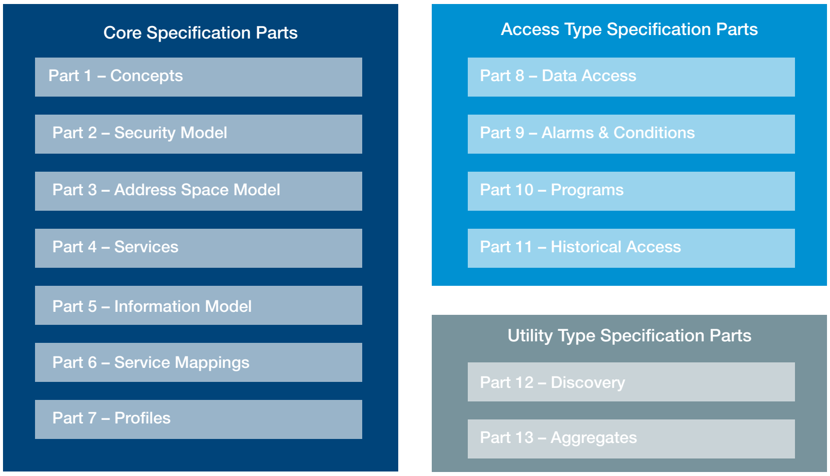
→ **1. Basic specifications.** These contain the basic concepts of the OPC-UA technology and the security model, plus an abstract description of the OPC-UA metamodel and the OPC-UA services. In addition they describe the concrete OPC-UA information model and its modeling rules, plus the concrete mapping 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 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.

WEBSITE AND EVENTS

A further source of information is the global website of the OPC Foundation plus regional sites for 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.



IEC62541: OPC-UA specifications

Source code and certification

SOURCE CODE AND TEST TOOLS

To ensure compatibility, the OPC Foundation offers 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.

→ 2. Example Code. Besides the communication stacks, which basically contain the protocol implementation only, the OPC Foundation 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 suggests the use of commercial Toolkits and Software Development Kits (SDK), as they are offered by various OPC member companies.

→ 3. Certification program. For testing and certification of logically correct behavior, the OPC Foundation offers 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.

→ 4. Interoperability workshops

The OPC Foundation holds three week-long interoperability workshop (IOP) per year, at which companies 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.

Laboratory – Certification

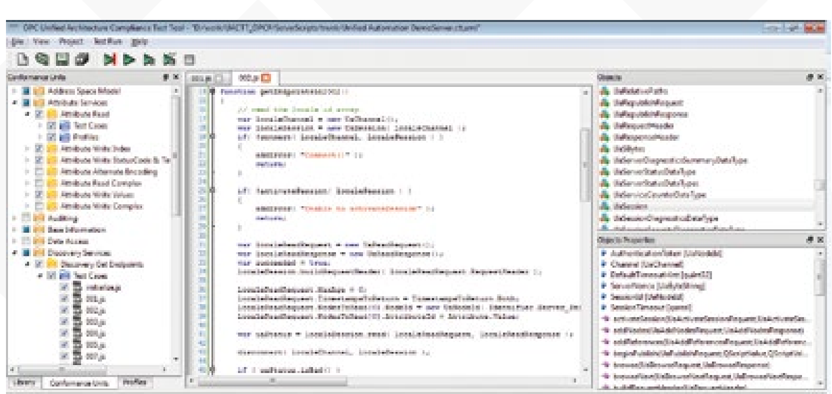
End users and integrators are encouraged to only use certified OPC products in productive environment. OPC server and client products which were tested in one of the independent certification laboratories, are recognizable by the „Certified" logo. These test labs are accredited by the OPC Foundation and follow the defined test scenarios to guarantee that your product complies with the following:

→ **Compliance** to the OPC Specifications
→ **Interoperability** with other vendors' products
→ **Robustness** and recovery from error conditions
→ **Efficiency** of CPU, RAM, and bandwidth etc.
→ **Usability** ensures a good user-experience

TEST TOOLS AND QA

There are different test tools available to validate the correct function of an OPC-UA server or client product. OPC Members have access to all the tools and thus can easily build up a comprehensive test environment. Especially the OPC Compliance Test Tool (CTT) implements several hundred test cases and provides a functional test with enormous test coverage. The script based tool is permanently enhanced with new test cases and hence also covers enhancements specification in a timely fashion. Additionally it can be extended with your own product specific test cases. The CTT is a test platform which perfectly can be integrated into your company's automated system and regression test.

»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.«
Liam Power, MatrikonOPC



OPC-UA: Integration into Products

CODE AND ADVICE

The OPC Foundation manages 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, many decide 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.

This is where the toolkits come in by consolidating generic functions such as connection management, certificate management and security features. Using toolkits e.g. developer frameworks offers advantages for implementation and time to market.

EXPERT KNOWLEDGE

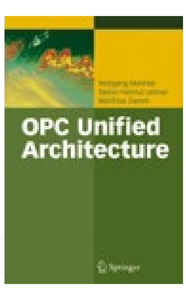
A number of companies around the world offer commercial support for the integration of OPC-UA communication technology in existing products and the implementation of new products, ranging from advice and developer training to selling software libraries and development support right up to long-term support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

The developer frameworks e.g. toolkits are available at attractive prices as binary “black box” components or includingcomplete 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.

OPC
From Data Access to
Unified Architecture
Available at
OPC Foundation only



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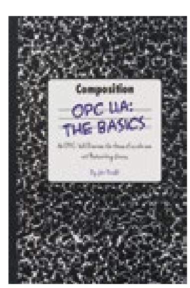


Composition
OPC-UA:
The Basics
ISBN: 978-1482375886

FURTHER INFORMATION ABOUT TOOLKITS IS AVAILABLE FROM …

→ HBSoftSolution, MatrikonOPC, 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

Engineering: Interoperability by combining AutomationML with OPC-UA

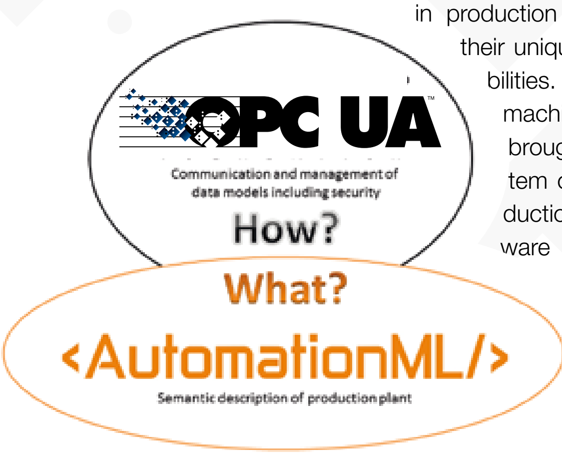
»Requirements for the factory of the future«

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 shall be capable of producing customer-specific products in ever new variants. Those involved in engineering and production shall react on short notice to changed customer wishes, even after order intake. Uncertainties in markets lead to versatile factories and manufacturing equipment. Industrie 4.0 is the strategic framework program for the German industry entrenching growing digitalization in its construction bureaus and production halls. A wide range of individual industrial-suited standards is available, which now have to be purposefully consolidated.

Also the Industrie 4.0 ICT architecture needs the ability to adapt to changes – either by adding new equipment or production processes into the system or by changing existing production systems e.g. because a new, additional product variant has to be manufactured. If in the future work pieces, machines or material flow systems communicate with each other, they need a common language and a universal transmission channel. Only both components collectively lead to inter-operable solutions.

A central idea of Industrie 4.0 is that objects involved in production comprehensibly describe their unique identity and their capabilities. If then new components, machines or equipment are brought into the production system or changes appear in production, the appropriate software modules can quickly and efficiently adjust the configuration of ICT systems.



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 companion standard that was mutually developed between OPC Foundation and AutomationML e. V. aims at combining the two technologies such that in case of modifications in the factory data is communicated currently, consistently and reliably. 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 model at the time of physical integration. Component suppliers identify the information required for this purpose in advance and include it in the components themselves. Machine builders or system integrators thereby save approximately 20 % time in the case of initial start-ups or changes in machines and production systems for the physical and informal integration of components on the basis of the “plug & play” principle. Configuration mistakes will be reduced because the data flow is automated. Even greater potential can be opened up if data required for the configuration of an HMI or superimposed MES are taken from the engineering systems on which they are based and stored directly in OPC-UA information models as AutomationML objects.

Offshore Oil & Gas: OPC-UA Information Model for MDIS

»Standardization between Master Control System (MCS) and Distributed Control Systems (DCS) simplifies connection«

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

The MDIS Network:

ABB
Aker Solutions
BP
Chevron
ConocoPhillips
Dril-Quip
Emerson
ENGlobal
ExxonMobil
FMC Technologies
GE Oil and Gas
Honeywell
Kongsberg
MOOG
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Yokogawa

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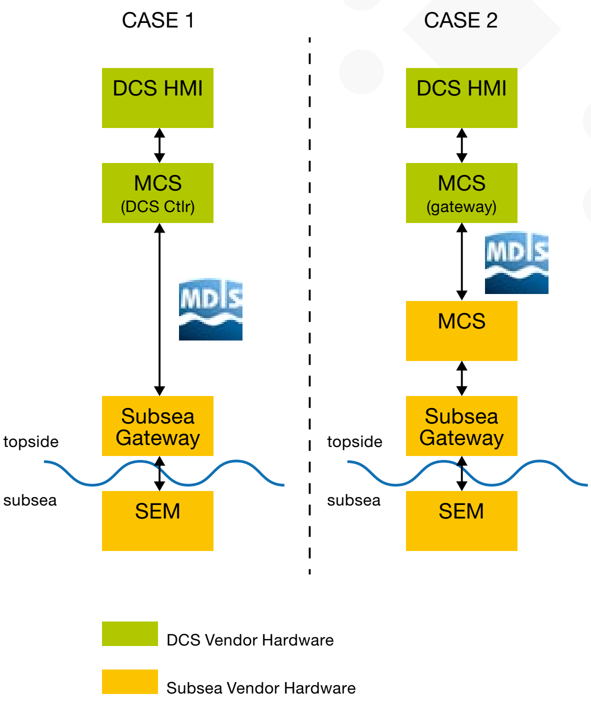
In the oil and gas industry the major operating companies, oil & gas service companies, DCS vendors, subsea equipment vendors and systems integrators all have their unique requirements and rules when it comes to their own software and hardware systems. But on the offshore oil and gas platform all of these systems have to come together and work seamlessly. Further these offshore platforms are many times located in harsh environments such as the North Sea or at least inaccessible such as platforms that are near the limit of helicopter travel.
Typically the starting point for these platforms is engineering efforts in excess of a year and costs in the millions of dollars. And changes to systems after it has shipped are very expensive if possible at all.
In 2010 the oil and gas companies banded together to form an organization, the MDIS Network, to decide on the standard communication interface and develop a standard set of objects to link the Subsea gateway, the MCS and the DCS.

MDIS did not wish to build something new, the organization had to select a protocol upon which to build their standard. Their initial list of many protocols, was narrowed down by performance evaluations and detailed technical evaluations, finally selecting OPC-UA.
Formed by an unique set of requirements by each MDIS member, the key shared features included the support for multi-platforms and information modeling capabilities, which helped the group decide on OPC-UA.

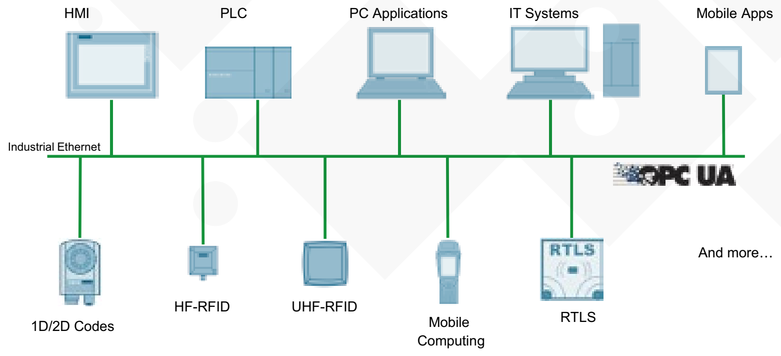


Identification: OPC-UA in RFID

»A unified communication standard is revolutionizing the AutoID industry«

Olaf Wilmsmeier, HARTING IT Software Development GmbH & Co. KG

The trend towards increased automation is demanding systems that are more heterogeneous. New challenges and tasks can only be dealt with properly when communication nodes are able to exchange all relevant information directly in a flexible manner.
UHF RFID and other AutoID technologies are clearly the key technologies for implementing the concept of „Integrated Industry“. That is why it is so critical that these technologies are integrated into complete solutions as simply as possible.
Thanks to its advantages and broad, cross-vendor acceptance, OPC-UA has emerged as a viable communication standard in the automation industry. One of the many benefits that OPC-UA offers is the ability to pre-define data models of device groups in so-called companion specifications. These specifications contain the essential functionality, including the data type description of the individual variables, transfer parameters and return parameters.



AutoID topology with OPC-UA

HARTING already initiated such cross-vendor standardization for the AutoID industry back in 2013. Motivated by the knowledge that an accepted, standardized communication interface for AutoID devices would make the work of system integrators significantly more efficient, HARTING and Siemens raised the OPC-UA issue in an AIM Germany (Association for Automatic Identification and Mobility) working group at the beginning of 2014. Together with other industry leaders, this association decided to define a companion specification for AutoID devices in cooperation with the OPC Foundation.
Now, thanks to a year of dedicated work by all those involved, this goal has become a reality. The first official draft of this new unified communication interface for AutoID devices was presented at the 2015 Hanover Fair.
The advantage of such a companion specification is quite evident. As more manufacturers follow this recommendation and implement their communication interfaces accordingly, it will be possible to integrate various devices, even from different manufacturers, more quickly into new applications. This saves time and provides improved protection for our customers‘ investments.
This specification can also be extended with device-specific or vendor-specific customizations, because of OPC-UA‘s object-oriented design. Manufacturers can thus retain their unique features while still relying on a common, widely accepted communication platform.

BECKHOFF

PLCopen ERP MES HMI IEC 61131-3 C T R L OPC UA

Integration: OPC-UA Client and -Server in controller

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

Stefan Hoppe, Beckhoff Automation,
Chairman of the common working group PLCopen & OPC Foundation, President OPC Foundation Europe

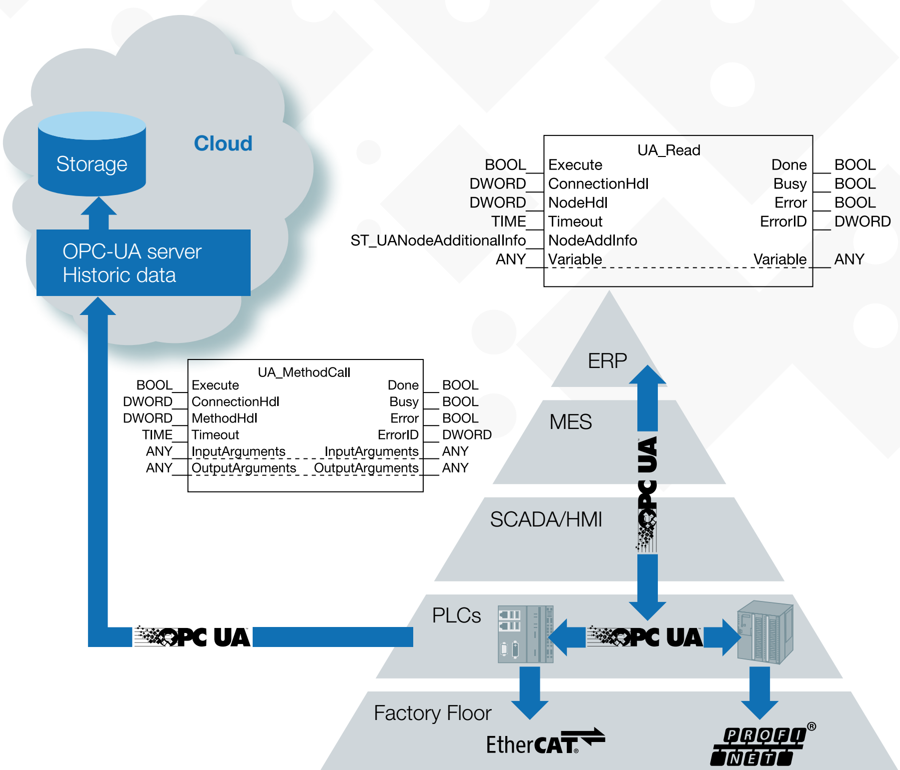
The interaction between IT and the world of automation is certainly not revolutionary, but is based on the long-established model of the automation pyramid: The upper level initiates a data communication (as a client) with the level below, which responds (as server) cyclically or event-driven: A visualization, for example, can request status data from the PLC or transfer new production recipes to the PLC.
With Industrie 4.0 this strict 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 Industrie 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 Industrie 4.0.



Vertical: OPC-UA plus UMCM – The "USB plug" in between SPS and MES

»Vertical Integration: Roadbook for the next level of industrial integration«

Angelo Bindi, Senior Manager Central Control and Information Systems Continental Teves – founding member of Board MES D.A.CH association

In an industrial environment, it is crucial that the symbols, language and meaning of content is standardized and the same for all systems. In the MES D.A.CH association with UMCM (Universal Machine Connectivity for MES) an integrated communication model for machine data towards higher-level systems that is optimized for the lowest common denominator, was implemented. Sixty-three member companies promote and optimize this model since more than 2 years and many suggestions and improvements from members have been incorporated and implemented in the current version 1.7.

Furthermore it is necessary to follow a secure, fast standardized, easily recognizable and if necessary extendable route. OPC-UA offers an unrivalled unified, secure across different security layers and nevertheless extendable architecture. Optimal bidirectional communication is thus assured, also for the future.

Based on OPC-UA, the MES D.A.CH association together with the OPC Foundation offers function blocks on the basis of IEC 61131-3 for various PLC suppliers and also in the format of high-level languages that enable convenient and fast implementations.

This is an efficient and simple method for raising systems to the next level of industrialization and making them fit for IoT and Industrie 4.0 applications.

»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 secure and can be integrated horizontally and vertically, from the device level right into ERP systems, i.e. OPC-UA. We then have an Industrie 4.0-capable system or a so-called cyber-physical system (CPS) that is independent of the location of the stored data.« **Angelo Bindi**

AREVA
forward-looking energy

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.

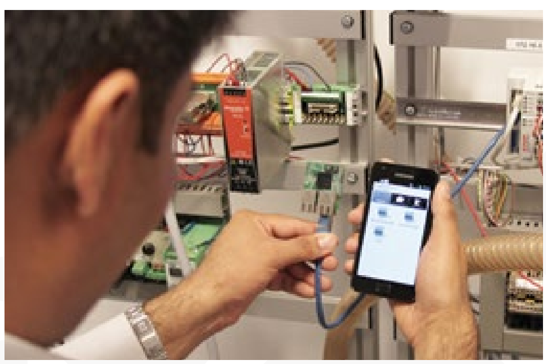
Fraunhofer IOSB-INA

inIT Institut für industrielle Informationstechnik

Scalability: OPC-UA at chip level

»OPC-UA at chip level as an enabler for Industrie 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)



Industrie 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.

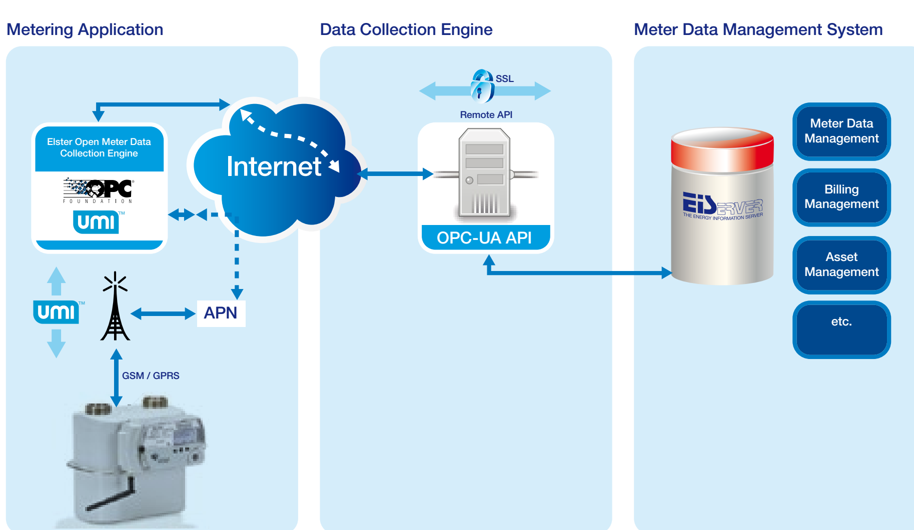
»OPC-UA being a highly scalable technology enables a seamless exchange of information between sensor, controller and ERP-Systems. In the next steps, OPC-UA is envisioned to be used to describe the semantics of various services for a Smart Factory.« **Jürgen Jasperneite**

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“.
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.



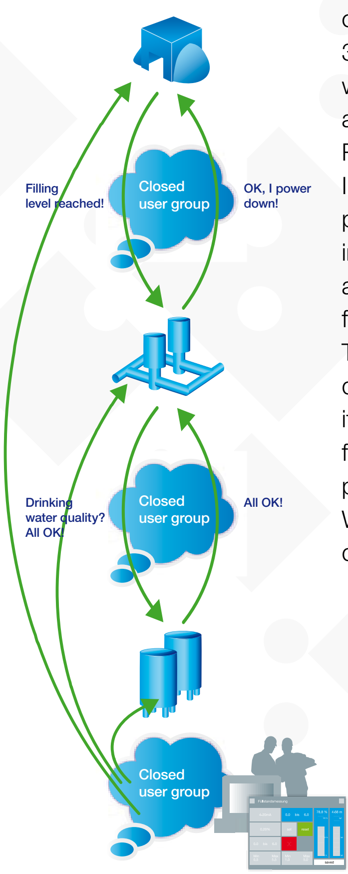
ZWAV

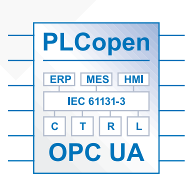
Horizontal: OPC-UA enables M2M and IoT

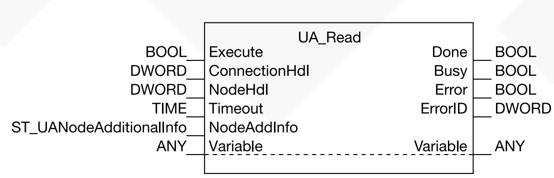
»Intelligent water management – M2M interaction based on OPC-UA«

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

If we regard some of the basic concepts of 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 km^2:
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.







RENEWABLE ENERGY

OPC-UA for monitoring offshore wind farms

»OPC-UA ensures high availability in Offshore«

Adwen
AN AREVA GAMESA COMPANY

Eike Grünhagen, Adwen GmbH

OPC-UA was the favored technology in 'Alpha Ventus', an offshore wind park test site in the North Sea, 45 kilometers from the German coast. The fully automated wind turbines controlled by a Windows Embedded CE based controller with IEC6-1131-3 logic and OPC-UA server are connected to a .NET based OPC-UA client application in an onshore control room. Compared to other open standards the inherent security and authentication mechanism of OPC-UA was the determining factor for this decision. With a complex network infrastructure including different subnets and domains, connected via routers and protected by firewalls, configuration and administration becomes a difficult and time-consuming task. In the past VPN tunnels for secure transmission and remote desktop connections were used. Now, with encrypted transmission, user authentication and audit functionality integrated into OPC-UA, access is possible down to individual data points.

»The integration of OPC-UA client functionality into our SCADA software was an important step towards secure control and monitoring across remote networks, as required in the offshore wind sector. High availability of system access is especially in offshore indispensable.« **Eike Grünhagen**

Vertical: OPC-UA from production right into SAP

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

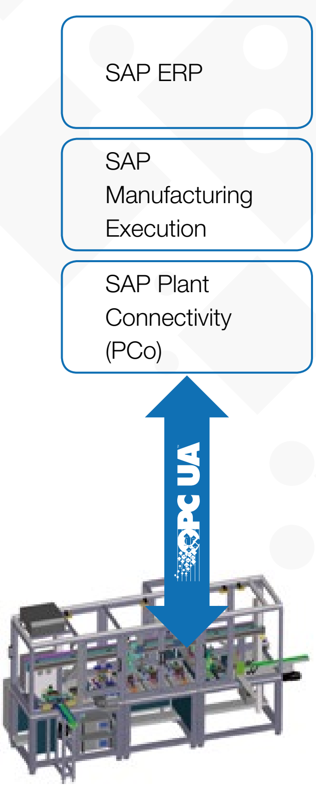
Roland Essmann, Elster GmbH, project manager for Manufacturing Execution System (MES)

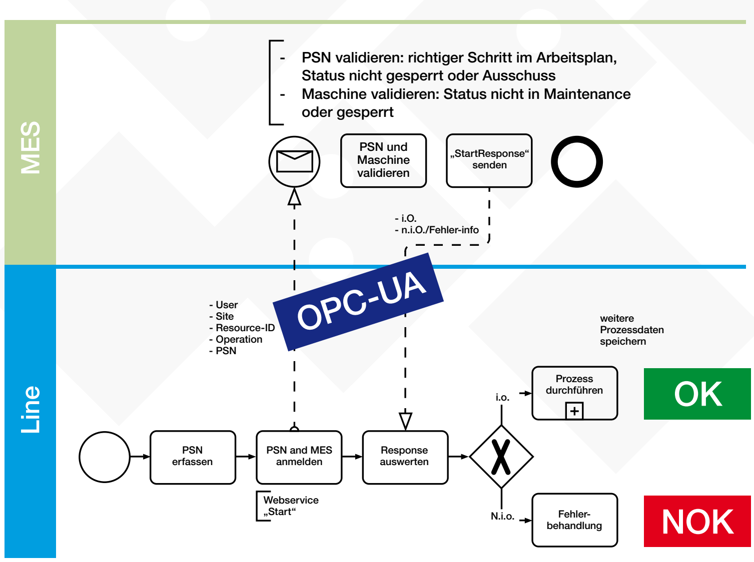
Rüdiger Fritz, SAP

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 Industrie 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 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. 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 control number 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 Industrie 4.0 has already been settled in practice: The communication between product and plant will take place via OPC-UA.





Cloud: OPC-UA for IoT up into the cloud

»The road to industrial cloud analytics leads through OPC-UA.«

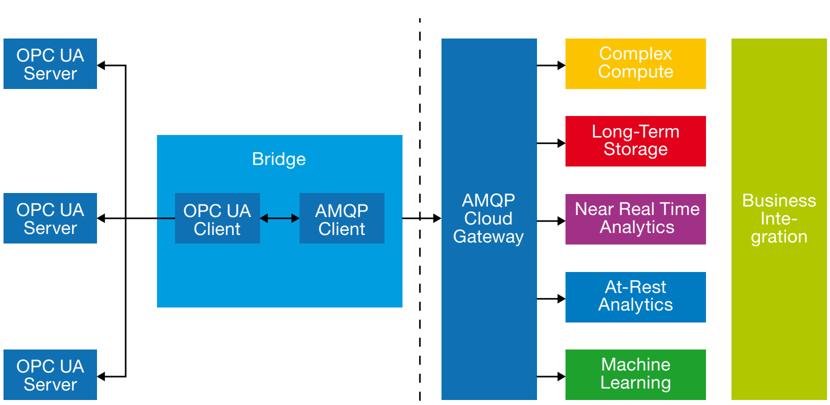
Clemens Vasters, Architect, Microsoft Azure IoT

"Internet of Things", "Industrial Internet" and "Industrie 4.0" all imply an increasing convergence of operational technologies and information technologies. The OPC Foundation's Unified Architecture standards family is an important foundation for this convergence process, providing a common software and metadata abstraction for a broad variety of industrial equipment. From an IT perspective, OPC-UA is a standardized programming interface (API) for any type of industrial machinery – it is the connected factory's API.

OPC-UA brings simplicity through standardization which facilitates fundamentally more cost effective, robust and secure integration - all critical enablers for IIoT and Industrie 4.0 adoption. OPC-UA also serves as an ideal gateway technology to bridge to the cloud and leverage transformational capabilities for data management, insights, and machine learning applied to industrial automation. The cloud enables on-demand access to compute, data storage, and advanced analytics capabilities that are difficult to stand up for each production facility. Optimization of production processes and equipment uptime across dispersed global facilities is now possible with capabilities like predictive maintenance, leveraging limitless compute, data processing and advanced machine learning algorithms from globally available cloud services. Equipment and service providers can develop innovative new service-centric business models around product and process platforms.

Its standardized interface makes it very simple to create a cloud bridge, some of which are already available from OPC members. The bridging capability is a software component acting as a client towards one or several OPC-UA servers relaying data to a cloud-based messaging gateway, often using the robust ISO/IEC standardized AMQP 1.0 protocol. Communication from the cloud to the machine can be securely accomplished by placing a message into the gateway for pickup, in a broker-mediated communication model that provides as secure a communication path as any VPN network.

As part of our commitment to openness and collaboration, Microsoft is dedicated to working with OPC Foundation in providing a reliable and secure platform based for industrial applications on OPC-UA from factory devices to the cloud based on robust open standards technologies.



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 Industrie 4.0 and Internet of Things«

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

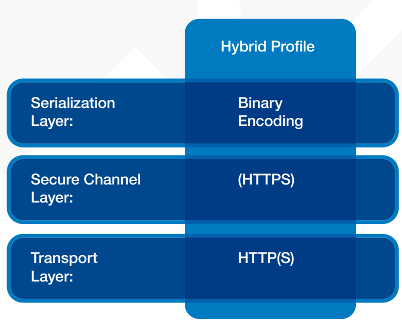
At the Institute of Automation it has been recognized early on that also in the field of industrial SCADA systems the trend is towards mobile applications. Due to the continuously growing variety of handheld devices, browser-based solutions are especially suitable.

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.)	✓

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

OPC EUROPE
Huelshorstweg 30
33415 Verl
Germany
stefan.hoppe@opcfoundation.org

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

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

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www.opcfoundation.org