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Trends in Industrial Communication and OPC UA

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***Abstract*— The paper deals with trends in industrial communication and with the question how to integrate existing communication and information technologies into automation. What new solutions OPC UA offers to today's modern industry? And how to capture the complex issue of Industry 4.0 in education? Answers to these questions are very important today.**

***Keywords*—Industry 4.0, industrial communication, OPC Unified Architecture, education, Time Sensitive Networking –TSN, ICT**

I. Introduction

The huge variety of industrial mechatronic systems, automation tools, and industrial communications systems is subject to a new challenge and need to unify and share the data of individual components of industrial enterprises in line with trends known under Industrial IoT or broadly as Industry 4.0.

OPC UA (Open Platform Communication Unified Architecture), which is a widely recognized standard in industrial automation for interoperability and data exchange from sensor and actuator levels through control and communication systems to central servers and clouds, plays a key role in this process - Fig.1.

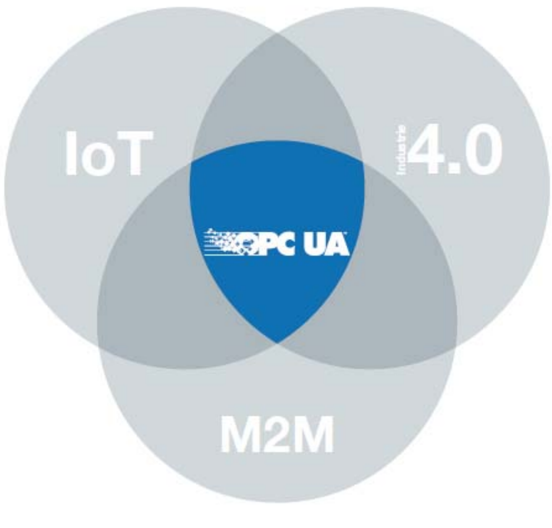

Fig. 1 - Remote device access with OPC UA is the common interest IoT, M2M and Industry 4.0, [3].

In the framework of educational projects (KEGA), new methods and forms of teaching will be developed focusing on daily attendance and distance learning methods, which will be accessible and creatively elaborated by extensive knowledge not only for students but also for the broad professional public in the form of eLearning multimedia forms.

II. Trends in Industrial Communication

One area that needs to be addressed is real-time industrial communication. At the center of standardization, the so-called "M2M" (Machine-to-Machine) communication developed by a number of companies. The increasing degree of automation and robotization of industrial production requires the development of new production organization approaches and mutual communication of individual components of production (the subject of communication is also the products themselves – e.g. AutoID) using the latest trends in ICT.

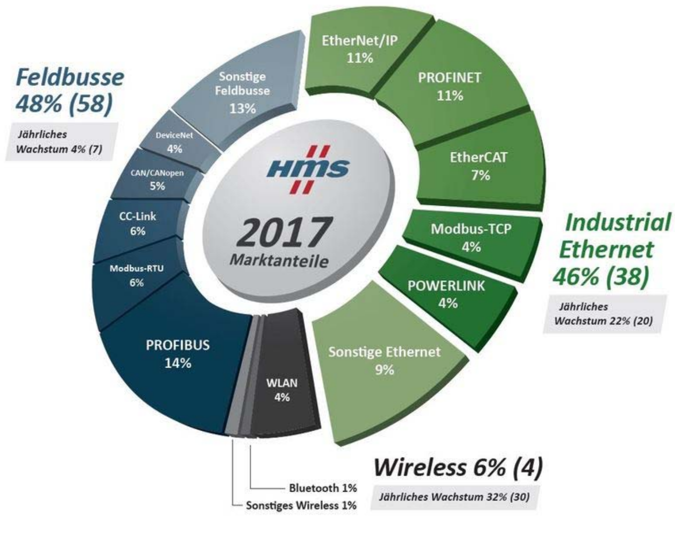

Fig. 2 – Consolidated estimation of HMS for 2017 in factory automation. Image: HMS Industrial Networks, [4].

Consolidated estimation of HMS for 2017 based on the number of newly installed nodes in 2016 in factory automation as well as various market studies and own statistics is in Fig. 2. Both traditional fieldbuses (growth rate of 4%) and Industrial Ethernet (growth rate of 22%) are growing, but Industrial Ethernet is growing faster. According to HMS, wireless networks are the fastest growing segment in industrial

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communication with a growth rate of 32% (2016: 30%). HMS estimates the market share of newly installed wireless networks at around 6% in 2017 (2016: 4%). WLAN and Bluetooth have established themselves as a standard solution for mobile or rotating applications as well as the basic technology for the use of smart devices as a replacement for classic HMIs.

The arrival of Industrial Ethernet (IE) in the first decade of the new millennium has created some expectation that it will be able to unify the communication structure of the enterprise. These expectations only partially fulfilled. More successful IE protocols such as Profinet have gradually integrated several classical fieldbuses (2006: Profibus, Interbus, DeviceNet, ASi, 2007: HART, FF 2011: CANOpen) using proxy devices.

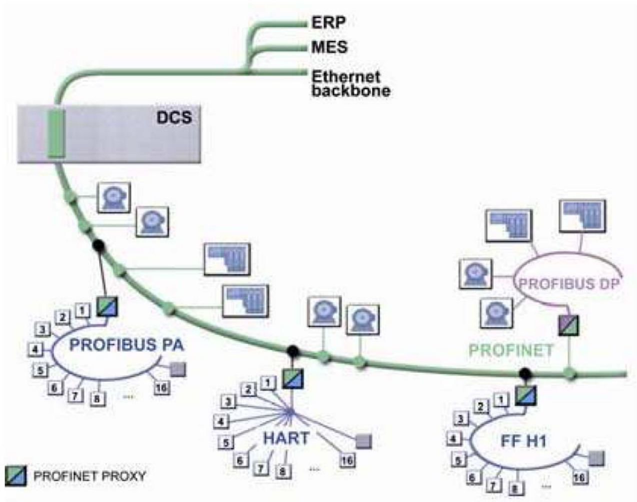

Fig. 3 Example of integration with Industrial Ethernet in process automation [5].

At the same time new IE-based protocols have been developed. After 2012, we have more than 20 Communication Profile Families (CPFs) that have addressed real-time issues in a variety of ways. The "fastest" real-time protocols are today: EtherCat, Profinet, PowerLink and Sercos. All four of the above-mentioned protocols, alias of large industrial clusters and other organizations such as CiA (CAN in Automation) and companies, have signed cooperation agreements and signed Memoranda of Understanding with the OPC Foundation [1] to promote the development of ICT in the digital environment. The result of these agreements with the OPC Foundation is to allocate the communication space as follows. These successful IE protocols remain the communication space at the field level (or factory floor), see Fig. 4. The OPC UA protocol unifies vertical and horizontal higher production levels.

It should be noted that Industrial Ethernet protocols to achieve isochronous real time did not use TCP / IP Internet Protocol (at most UDP / IP) but other, in practice, successful solutions mostly based on HW. "Internet access" is implemented on gateway devices that separate the real-time segment.

III. OPC Unified Architecture

OPC UA organization provides industrial standard OPC UA for interoperability and horizontal and vertical integration of information from sensors/actuators/machines to ERP (Enterprice Resource Planning), Fig. 4.

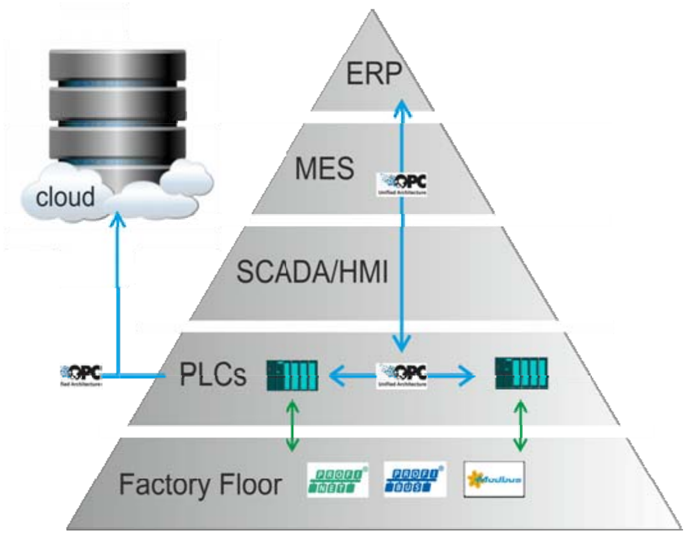

Fig. 4 Vertical and horizontal integration with OPC Unified Architecture in factory automation [4].

Firstly, OPC UA was focused only on the needs of industrial automation, but OPC UA was independent of vendors and operating systems, and it quickly became an appropriate solution for interoperability for other "markets and domains". Manufacturers' machines and equipment are "described" in the OPC UA by data structures and interfaces, and then security credentials are configured.

The various network transport mechanisms are integrated for data and information transfer for the level of operational management for both IT and cloud solutions, so that the best mechanism is chosen for the different scenarios. OPC UA technology has been recommended for communications technology in German Industry 4.0. Federal Office for Information Security (BSI) has thoroughly analyzed data security in the OPC UA, resulting in very positive reviews. Many other organizations have used the possibility of modeling and OPC UA confirmed the seamless integration of information between previously incompatible systems. This leads to the removal of barriers to small and medium-sized enterprises in setting up and expanding industrial communications in the context of Industry 4.0.

An example of addressing the issue of unified communication is also the cooperation of the VDMA Machine Vision (Mechanical Engineering Industry Association) and OPC Foundation. Machine vision systems have become an indispensable part of industrial production.

No other current component in the production process collects such data as machine vision. This resulted in the so-called " OPC UA Machine Vision Companion Specification to create a standard for communication and networking of camera systems within Industry 4.0.

The vision of the OPC Foundation is to offer a multi-domain platform for interoperability and data exchange from sensors to enterprise systems management. OPC UA is more than just a protocol. OPC UA is rather a framework for the representation and exchange of object-oriented data and information.

For information exchange OPC UA offers two communication mechanisms:

- The first is a client-server model where the client accesses the information provided by the server through defined services.
- The second method of communication is OPC UA PubSub, which is aproximately (2017) in the pilot operation (yet mostly without TSN).

Until recently, OPC UA has had limitations in terms of critical real-time processes. In this respect, the "publisher-subscriber" model, known as OPC UA PubSub, and real-time communications using the time-sensitive network (TSN) are being developed and verified.

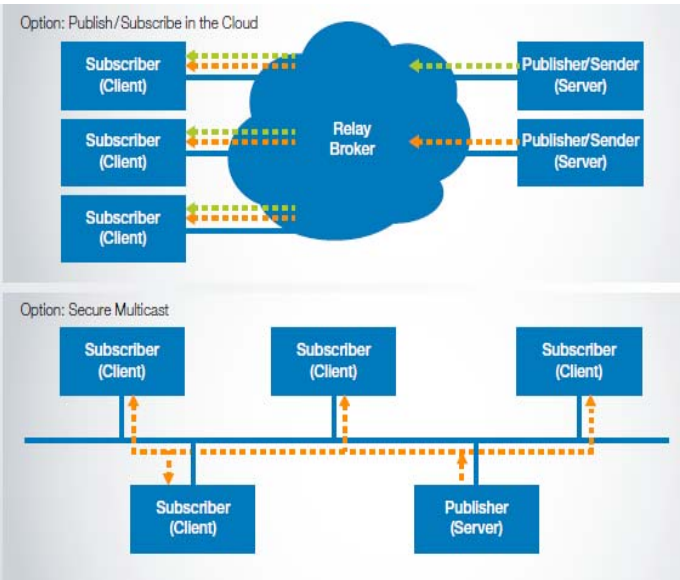

Fig. 5. Two methods of OPC UA PubSub communication

Two methods will be available to support different scenarios [3], Fig. 5:

1. OPC UA PubSub for Messaging over local networks (LAN). Data will be multicast over UDP by an OPC UA Server (published) for consumption by any number of authorized OPC UA Clients (Subscribers). This will allow extremely efficient data distribution without brokerage. OPC UA PubSub methods utilize well-established protocols like the User Datagram Protocol (UDP) for Secure Multicasting and Time Sensitive Networking (TSN) for deterministic networking.

2. OPC UA PubSub for Messaging over global networks (WAN/Cloud). This method provides a secure and highly scalable method for sharing data from any number of OPC UA publishers with any number of OPC UA enabled sub-scribers. For data sharing across global networks, OPC UA PubSub specification defines mappings on the most relevant messaging protocols, like MQTT and AMQP.

The communication platform OPC UA, which enables data exchange from sensor to cloud, has been chosen as the reference standard for Industry 4.0. The Publish/Subscribe enhancement for OPC UA now allows multicast communication between thousands of sensors and the cloud, and also coordination between machines. OPC UA in combination with IEEE TSN enables open data exchange between industrial controllers from different vendors, making the vision of open, real-time machine to machine communication a reality for all applications, including those with critical safety requirements.

The main source of information are the specifications as an IEC62541 standard series. Currently 14 OPC UA specifications are available [3].

IV. TIME-SENSITIVE NETWORKING

Time-Sensitive Networking (TSN) is a set of IEEE 802 Ethernet sub-standards that are defined by the IEEE TSN task group. These standards enable deterministic real-time communication over Ethernet. TSN achieves determinism over Ethernet by using time synchronization and a schedule which is shared between network components. By defining queues based on time, Time-Sensitive Networking ensures a bounded maximum latency for scheduled traffic through switched networks. This means that in a TSN network, latency of critical scheduled communication is guaranteed.

All participants and all switches within the deterministic TSN-network must be time synchronized and must be configured to be able to transmit the data to the final receiver (scheduling). TSN uses the IEEE1588 – PTP (Precision Time Protocol) for synchronization. TSN is a set of extensions to the Ethernet standard defined in IEEE 802. OPC UA needs at least two of these Ethernet enhancements:

a) 802.1 AS-Rev for time synchronization and

b) 802.1Qbv for scheduling.

TSN implements the Planner into Layer 2 (of OSI model) instead of Layer 4. This achieves low latency of TSN.

The Time Sensitive Networking and OPC UA PubSub standard were adopted by large companies that support Profinet [5], EtherCat [7], PowerLink [8] and others [4, 6, 9].

V. COMPLEX SOLUTION AND UNIFIED PLATFORM

The high degree of automation of discrete and continuous processes has resulted in many excellent solutions in multiple application areas, but lacking interoperability. Individual industrial devices need to communicate not only within corporate platforms but anywhere, i.e., in the global network. This is a new requirement and a new Industry 4.0 trend dimension. Each device is universally addressable (Industrial IoT), plug and work and produce, secure, accessible to the administrator (authentication) and capable of self-diagnosis.

A comprehensive solution, however, does not mean to start building everything on a green field. The OPC Foundation proceeds by integrating existing solutions of individual companies or groups and various professional associations, which will be embedded in a single information, communication and data model that is internally structured. As an example is the Unified OPC UA object on the Fig. 6. It also provides users with the necessary information and ready SW components for interoperability creation within a common platform.

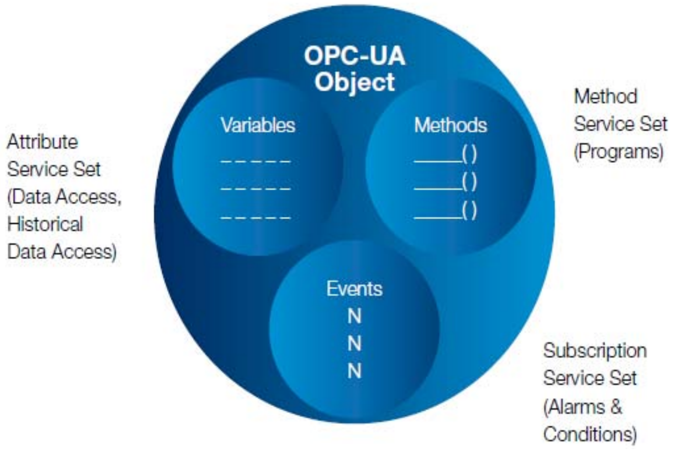

Fig. 6 – Uniform OPC UA object, [3].

OPC Foundation’s Standards Committee prepares technology-specific information models (for sensors, actuators, automation elements and control systems) that already exist or are in development-preparation. There are, for example, the following technology-specific information models:

- OPC-UA for Field Device Integration (FDI). Integrates EDDL (IEC 61804) a FDT (ISA SP 103)
- OPC-UA for Programmable Controllers: PLC Open IEC 61131-3 (Allows portability of programs)
- 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)

In any case, the OPC UA standard has solutions for the requirements set forth in Industry 4.0 goals and visions such as: independence of communication technology (from manufacturer, sector, OS, programming language), interoperability, scalability of devices (from small sensors, PLCs, PCs to smartphones), secure and reliable horizontal and vertical communications and many more.

VI. MODERNIZATION OF EDUCATION

New project KEGA called "Convergence of automation and advanced ICT" is intended for the modernization of education. The project deals with the development of a modern knowledge and experimental platform for teaching mechatronics with the emphasis on its component parts: automatic control and information and communication technologies. The huge variety of industrial mechatronic systems, automation tools and industrial communications systems is subject to a new challenge and need for unification and sharing the data of individual components of industrial enterprises in line with the trends known as Industrial IoT or the broader considered concept Industry 4.0. The key role in this process plays the OPC UA (OPC Unified Architecture) - a widely recognized industrial automation standard for interoperability and data exchange from the sensors / actuators level through control and communication systems up to central servers and clouds. Within the project, new learning methods and forms will be developed, focusing on daily attendance and distance learning methods, which will make extensive knowledge available (by creatively processing) not only for students but also for the broad professional public in the form of e-learning and multimedia forms.

The challenging motivation for project submission was the need to modernize the study programs Automotive Mechatronics (Bc.) and Applied Mechatronics and Electromobility (MSc) according to the latest development trends in industry, where the "big players" in the European and world industries are ready to create a unified digital platform for industries, according e.g. to OPC UA recommendations. Important motivation is the urgent social need for (lack of) a larger number of technically trained professionals for the automotive industry and its subcontractors in Slovakia.

It is planned within the project solution, not only to modernize the content and methods of learning, but also to build a teaching-experimental multimedia laboratory equipped with components necessary for the creation of educational multimedia materials (especially video and interactive electronic forms) in the subject field. At the Institute of Automotive Mechatronics of the Faculty of Electrical Engineering and Information Technology (FEI STU) in Bratislava there are experts who are prepared for integration and intersection of automation with information and communication technologies.

In the following overview of ten subjects, the theme Industry 4.0, which is relevant for the modernization of teaching in the given field, is phrased:

1. Intelligent Sensors and MEMS – IIoT ready, Field Device Integration - FDI, Industrial fieldbus integration, AutoID Systems.

2. SW development kits - OPC UA support for application programming in Java, C ++, .NET, Python.

3. Embedded microcomputer systems - OPC UA implementation, real-time clock synchronization, OPC UA Device.

4. Smart mechatronic systems - Machine vision according to OPC UA specifications (in collaboration with VDMA).

5. Communication systems and networks - OPC UA Pub / Sub, Time Sensitive Networking - TSN, Integration of Operational Devices, Interoperability, Gateways.

6. PLC Systems in Mechatronics - PLC Open, Semantic Interoperability by mapping IEC61131-3 into OPC UA Namespace.

7. Database and visualization systems - OPC UA Object: Data Access, Historical DA, Big data.

8. Automated systems for automobile production - digital twin, virtual and mixed reality.

9. Intelligent Mechatronic Systems - Cloud: Microsoft Azure IoT Hub with OPC UA access.

10. The CAD system and design of the MS - comprehensive view of IIoT and Industry 4.0.

VII. CONCLUSION

The OPC UA standard plays a key role in modern industrial communications systems. OPC UA goes beyond communication systems and is widely accepted as a reliable standard for data exchange and semantic interoperability. It provides secure communication especially in the upper hierarchy of industrial production enterprises up to the cloud. Other industrial communications systems retreat to the field level of traffic. OPC UA addresses all the requirements of Industry 4.0 on communication and information level RAMI 4.0. From an IT perspective, OPC UA is the programming interface of the “connected factory” and any other industrial facility and a critical enabler for Industrial Internet of Things (IIoT) as well as the Reference Architecture Model for Industry 4.0 (RAMI 4.0) adoption. The Time Sensitive Networking and OPC UA PubSub standard is expected to be both technically a business strategy for large industrial companies and has become a phenomenon for Industrial IoT.

Benefits of interoperability of products from different manufacturers is reflected in higher efficiency and further acceleration of production automation. This complex vertical and horizontal structured process is about creating a unified "digital environment" in the vast variety of existing automation tools. It is expected that a unified "digital environment" will not only eliminate many incompatibility difficulties and increase the flexibility of the means of production but will open new possibilities for optimization of manufacturing processes and decision-making based on artificial intelligence. This trend is supported by companies, industrial clusters and some states. It should also be an obvious part of education.

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