

## New Challenges for Interoperability of Control Systems

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### Introduction

Software is an integral part of modern control and automation systems. Information technologies merge with automation and control systems. This process is unavoidable and affects industry as well as education. A huge number of techniques and possible new Web applications for automation bring about new possibilities and requirements for control systems interoperability.

Now we are facing a market of new *smart* transducers and actuators that can be accessed by wired or wireless media locally or through the Internet. These transducers (and actuators) have to be precisely announced for automation fieldbuses or DAQs (Data Acquisition Systems) by networked industrial *devices profile*. Device profile allows addressing of data that can be transmitted to/from a field device. Concrete profile can be described by properties and appropriate *data structure* and makes interactions between different automation devices [1]. The concept behind the profile is simple: how to allow any device to be automatically discovered, installed and utilized by other devices and on a network.

### New tendencies in automation sphere

For a few years we have seen rapid changes in the merging of data and voice networks. Internet and Web technology is on its way to support distributed control systems and devices used in industrial automation, automotive electronics, home automation, etc.

How are convergence of technologies and digitization of appliances influencing the demands for industry automation? The Internet serves as a technology platform that enables an entirely new generation of consumer applications for distributed data: remote and distributed control, monitoring, SCADA (Supervisory Control and Data Acquisition) systems, visualization. Digital devices can be connected wirelessly to larger networks and the Internet as well, so client/server architecture is going to be a typical solution for data exchanging and processing.

Distributed control systems grow very fast and many of them have different data formats, due to coming from

different vendors. There are 9 different fieldbuses standardized by ISO. Data exchange between these fieldbuses (devices) used to be complicated or even impossible. The devices profile is a detailed specification written as a set of numbered normative statements. These statements use networking libraries or platform components and describe a core subset of specifications into an overall whole. The devices profile focuses on IP-capable devices which nowadays are becoming common. The device profile can be represented by an XML-file opening up machine readable specifications.

Now we are seeing tendencies of SCADA systems merging with Web services. Beside description of core specifications, the Web services architecture includes complementary functions that provide reliable and secure messaging that is very important for remote control or monitoring. Web services scenarios involve services already being deployed in the office, enterprise, and Internet.

The main task is to enable a base level of interoperability between devices and Web services. Do we have now suitable tools for this problem solving? The answer is a definite “yes”. Now consumers have got a modern instrument that allows creating of software for exchanging of data that are in different (or incompatible) formats. This instrument is Extensible Markup Language (XML) and family of related standards that support it. For example, DTD (Document Type Definition) or XML Schema allows using of device profiles for data structure describing and making interactions between different devices connected to a digital fieldbus. These new challenges of the internet technologies must be implemented in control technologies.

In [2] it was shown how XML can solve a problem by defining a basic schema for automation devices that allows describing the core functionality of field devices in a standardized way. In order to adjust the core description to a particular fieldbus technology, it is possible to insert the fieldbus specific properties via specific fieldbus schemas for each fieldbus technology. Different description languages are necessary if enterprise in its plants has different fieldbuses. XML gives the most

suitable solution of this problem because it fits well nearly all requirements and allows the adoption of the XML Schema.

### Web services that meet automation needs

Data acquisition and control techniques include (but are not limited to) many areas of data visualization and pre-processing. Web services today offer new possibilities for data exchanging what was impossible a few years ago.

A Web service is a software application identified by a URI (Universal Resource Identifier), whose interfaces and binding are capable of being defined, described and discovered by XML and supports direct interactions with other software applications using XML based messages via Internet-based protocols. Software components expose an automation function/service/data and can be accessed by another application over the Internet (Fig. 1). Digital control systems design today is mainly a programming task.

Which of Web services meet control and automation needs? SOAP (Simple Object Access Protocol) provides the definition of the XML-based information which can be used for exchanging of structured and typed information between peers in a decentralized, distributed environment [3]. SOAP message is formally specified as an XML Information Set, which provides an abstract description of its content.

SOAP service is used to encode the information in Web service request and response messages before sending them over a network. SOAP messages are independent of any operating system or protocol and may be transported using a variety of Internet protocols. Many SOAP implementations are bound to HTTP, but may support TCP/IP, MIME (Multipurpose Internet Mail Extensions), etc.

SOAP defines the standard format for XML messages and functionally is similar to RPC (Remote Procedure Call), CORBA (Common Object Request Broker Architecture) and RMI (Remote Method Invocation) - a set of protocols being developed by Sun's JavaSoft division that enables Java objects to communicate remotely with other Java objects.

RMI is, relatively, a simple protocol, but unlike more complex protocols such as CORBA and DCOM (Distributed Component Object Model) it works only with Java objects. CORBA and DCOM are designed to support objects created in any language. CORBA is an architecture that enables pieces of programs, called objects, to communicate with one another regardless of what programming language they were written in or what operating system they are running on. DCOM is an extension of the Component Object Model (COM) that allows COM components to communicate across network boundaries.

WSDL (Web Services Description Language) describes a Web services as a collection of ports and operations. WSDL specification provides an XML format for documents and describes the public interface to the Web service.

Automation networks in enterprise are dynamic, continually evolving to meet the demands of end users and applications. Each step in this evolution is the result of challenges, including increased bandwidth demands and convergence to IP on factory floor.

### XML for applications in industrial automation

Network infrastructure enables the distribution of information, regardless of time and distance. Web services provide a relatively easy way to integrate systems. XML is going to become the main programming tool for various Internet applications. The main protocols of Web services today are XML, SOAP, and WSDL [4].

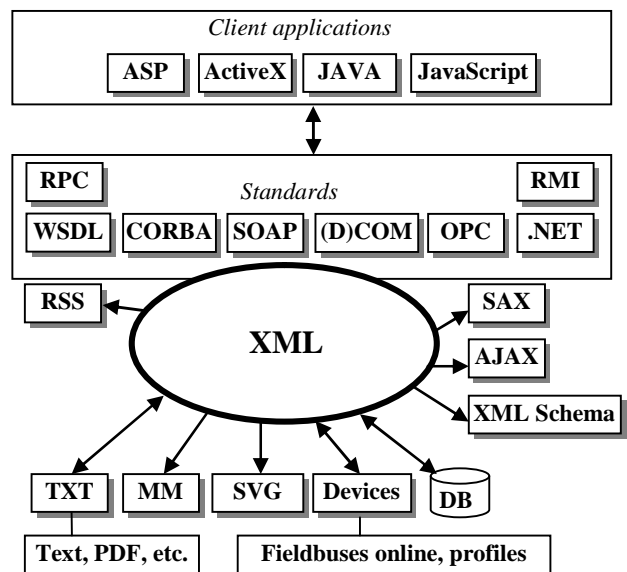


Fig. 1. XML as the description technology (MM-multimedia, SVG – Scalable Video Graphics)

XML lies at the core of Web services and allows encoding all communications to a Web service. Because all communication is in XML, Web services are not tied to any operating system or programming language.

Will XML influence the industrial automation? The answer is positive, because today we can see a huge amount of different applications that are written and formatted in XML as well as in its family of related technologies.

Why is XML so popular today? XML is a public platform independent standard. XML allows DTD and more modern XML Schema. An XML Schema (also referred to as XML Schema Definition (XSD)) describes the structure of an XML document. XML Schema is useful for automation needs because allows description of devices profiles. XML Schemas are more powerful than DTDs.

AJAX (Asynchronous JavaScript and XML) technology is becoming more and more popular because it is a cross-platform technique usable on many different operating systems, computer architectures, and Web browsers as it is based on open standards such as JavaScript and the DOM (Document Object Model). Many APIs (Application Programming Interfaces) and

applications programs allow the creation and manipulation of XML data easily.

XML has become a de-facto standard for data transmission through the Internet. XML standard and related data presentation formats (XSL, XSLT, query languages (XQuery, XPath) are defined by World Wide Web Consortium (W3C).

XSL (Extensible Styles Sheet Language) is a simple language that can make conditional expressions, counting, sorting, looping etc. and it is extensible. XSLT (Extensible Stylesheet Language Transformations) is used to transform an XML document into another XML document, or another type of document that is recognized by a browser like HTML and XHTML (Extensible HTML).

XPath is a language for navigation in XML documents and provides notation for selection elements within an XML document.

XML as universal and non dependant from platforms standard for information description is very suitable for hierarchical data structures and unification of transmitted information. XML can be stored in files, databases or the Web. Such XML features as user defined tags, hyperlinks, data self describing and separating them from behaviour influenced that XML has become the basis for all new generation data interchange formats. Properly nested tags allow categorizing data in a tree structure. The ability to specify new tags and to create nested tag structures makes XML a great way to exchange data, not just documents.

XML data are ready for syndication, since we only need to transform them to another format like RSS (Really Simple Syndication) by using XSLT and this XSLT style sheet may be generated automatically and applied for SCADA data visualization.

Data flow between networked control systems is being replaced by flow of information on TCP/IP basis. Each application area, especially embedded systems, has its own set of standards for information representing. Any programming language, running on any platform, can read a text and understand exactly what it means. XML's importance to the applications world is shown in the tools, specifications, platforms and software systems that have grown up around it.

In the manufacturing process each control system or subsystem works at a different level, but all of them rely on a common architecture for interoperability. Consistency of control information can be supported by representing the actual platform concepts in XML due to the structuring and validation properties of XML Schemas.

The main automation software concepts that allow the realization of such automation applications are *Classes* and *Objects* with their corresponding types and multiple hierarchical *Structures* based on the standard IEC1346 [4].

Another technology that is closely related to COM is OPC (OLE in Process Control). OPC was designed as the standard way to communicate plant devices with Windows based applications or any other system supporting COM. The OPC Foundation, in its turn, has been working on the specification of new standards that will use XML/SOAP for communication.

Unlike DCOM and OPC, XML is operating system independent, so any embedded controllers with an Ethernet connection can output XML. A process controller can be

from different manufacturers and support different programming languages, but as long as the XML content stays the same, the new system works just like the old one.

XML standard nature has many benefits regarding data manipulation, transmission and storage. The W3C has developed several XML related standards that fulfil the needs of different areas. This is particularly true nowadays, when many programming languages include libraries (typically based on the SAX (Simple API for XML) or DOM standards) to parse XML files.

Nowadays, there are several tools in the market that allow an easy mapping of XML data to relational databases. SQL (Structured Query Language) databases are powerful and useful, and they are not going away. However, they have never been a good fit for the Web. There are ways to solve the problem of effective, automatic conversion of XML data into and out of relational databases. Now SQL databases are changing to accept XML-based queries and produce XML-based results. For example, database vendors such as IBM, Microsoft, Oracle, and Sybase have developed tools to assist in converting XML documents into relational tables. Oracle XML SQL Utility models XML document elements as a collection of nested tables. Enclosed elements are modelled by employing the Oracle Object data type.

But many problems are much easier to solve with a native XML database and XQuery language than with a relational database and SQL. This means a simple embedded device can reach into database and extract necessary information without having structured query language and Open Database Connectivity drivers. Also this means that reporting software can read data from a process controller to determine when a tool needs replacement.

Once in XML format, objects can be sent through standard Internet communication channels and be addressed to any connected device. By means of XML transformations (XSLT), the XML stream can be converted into an XHTML or another format file. The presentation of the information would depend only on the display capabilities of the automation or control device.

As a step further, XML Web services could be used for real-time interaction with the control system objects. In order to represent SCADA databases using XML at least two documents are necessary:

- XML Schema (or DTD) for describing SCADA concepts and the system types;
- XML file containing the representation of all the objects in the system.

The XML Schema may hold the definition of complex types that model SCADA concepts (structures, objects, etc.) and the object types defined by the user. Thanks to the modularization capabilities of XML Schema, the types defined can be grouped in different Schema files for better maintenance. Validation tools allow checking the conformity of an XML file to an XML Schema.

XML describes the data structure but is not responsible for displaying data. There are two major ways to display XML in a Web browser:

- The first method is to translate XML into HTML for display – usually a scripting program

(JavaScript, VBScript) allows this translation.

- The second way is to use XSL to define the output format of the XML. Each style sheet describes rules for presenting a class of XML documents.

XML documents are presented by pattern matching. The formatting information is mapped into matched elements in the XML document that are described in XSL documents.

## Conclusion

Data interchange is critical in today's networked automation world. XML is the universal format for structured documents and data on the Web description. XML is particularly suitable for description of control systems databases and device profiles. Once described in XML SCADA systems data can be easily visualized on Web servers and browsers or transformed into other format, suitable for various applications.

No matter how industry fragmentation goes, it means that many products or systems can no longer be designed in isolation. An interoperability and data exchanging problem between different control systems and fieldbuses always was very important. Now programmers and designers have got a universal tool and family of W3C specifications that allow solving interoperability limitations. The following Web technologies are closely related to control technologies: XML, XML Schema,

SOAP, DTD, DOM, JavaScript, XSLT, MS .NET Framework, AJAX, XQuery and XPath.

In this paper it was shown how SCADA systems benefit from an XML infrastructure to achieve their objectives of interoperability. As well we have shown that XML documents can be used to represent the structures of control systems and their content. XML Schemas can be an excellent tool for modelling the concepts and data types of SCADA. Checking of consistency in XML documents can perform the instances of these types.

XML documents present a tree structure suitable for representation of aspect structures defined in the IEC 61346 standard, which are also organized in the form of a tree.

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Visualization of data from SCADA systems and control systems databases on Internet browsers is becoming an important constituent part of control system functioning. New Web technologies for automation systems allow effective way of various data formats exchanging that was earlier difficult or impossible at all. Modern today's Web technologies were analyzed and was shown that it is possible to solve interoperability problems between different fieldbuses or databases more effectively, when data structures of control systems and device profiles are described in XML. It was shown that XML and it supporting family of technologies allows new possibilities for description of control systems data base content and structure. Ill. 1, bibl. 4 (in English; summaries in English, Russian and Lithuanian).

**Р. Руткаускас, А. Липницкас, Ч. Рамонас, В. Кубилиус.** Новые возможности взаимодействия систем управления // *Электроника и электротехника*. – Каунас: Технология, 2008. – № 3(83). – С. 71–74.

Отображение в Интернете данных из SCADA систем или из баз данных систем управления становится неотъемлемой частью их функционирования. Новые современные Web технологии и сервисы предоставляют системам автоматизации эффективный способ взаимодействия и обмена данными, представленными различными форматами. В статье дан обзор возможностей современных Web сервисов и мотивировано показано, что внедрение новейших технологий разрешает более эффективно решить взаимодействие систем автоматизированного, что раньше было проблематично или совсем невозможно. Взаимодействие объектов управления может быть достигнуто при описании профилей приборов XML языком. Показано, что XML и его поддерживающее семейство технологий предоставляют новые возможности для описания содержания и структуры баз данных в системах управления. Ил. 1, библи. 4 (на английском языке; рефераты на английском, русском и литовском яз.).

**R. Rutkauskas, A. Lipnickas, Č. Ramonas, V. Kubilius.** Naujos valdymo sistemų tarpusavio sąveikos galimybės // *Elektronika ir elektrotechnika*. – Kaunas: Technologija, 2008. – No. 3(83). – P. 71–74.

SCADA sistemų ir valdymo sistemų duomenų bazių turinio atvaizdavimas internete tampa svarbia valdymo sistemų funkcionavimo dalimi. Naujos Web technologijos suteikia efektyvų būdą automatizavimo sistemoms keistis duomenimis, kurių formatai yra skirtingi. Analizuojamos šiuolaikinių Web paslaugų galimybės ir motyvuotai parodyta, kad, diegiant naujausių technologijų siūlymus galima efektyviau spręsti automatikos sistemų sąveikos, kuri anksčiau buvo problematiška arba iš viso neįmanoma, problemas. Valdymo objektų tarpusavio sąveiką galima užtikrinti, kai įtaisų profiliams aprašyti naudojama XML kalba. Parodyta, kad XML kalba ir ją palaikanti technologijų šeima suteikia naujas galimybes valdymo sistemų duomenų bazių turiniui ir struktūrai aprašyti. Il. 1, bibl. 4 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).