OPC UA: Examples of Digital Reporting Applications for Current Industrial Processes

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Abstract. The fourth industrial revolution is obviously well underway. Every day, we have the demonstration through new modes of commercial and industrial organizations. We are faced with major breaks as well related to the evolution of technologies as to the globalization of the economy with the emergence and the maturity of new actors: the challenge of the energy transition, the digital revolution, the protection of our planet, the convergences between human sciences and sciences. This paper presents different applications implemented for “Internet of Things” with Profinet network. These applications can be used on all of the company's processes as part of the Industry of the Future. The OPC standard appeared in the mid-1990s to facilitate exchanges between the world of automation and that of PC-based supervision. The latest OPC UA (Unified Architecture) specifications are now validated. With this new version, the OPC Foundation is revolutionizing its standard of communication between industrial equipment. OPC UA breaks the links that made it inseparable from Microsoft Windows. It can be deployed on all types of platforms. A Programmable Logic Controller (PLC) manages a manufacturing process. Seven operator panels also manage the various production recipes. Client n°1 makes the link to other Clients (reporting, E-mail, opening up to a scientific platform). The results are presented and detailed for numerous opportunities for industrial developments.

Introduction

The term “Industrial Internet” was coined by General Electric, founding member of the Industrial Internet Consortium (IIC: http://www.iiconsortium.org/). In this context, General Electric saw the Industrial Internet as a third wave in industry. Integrated Industry, Innovative Factory, Smart Factory are well known terms whereas, Industry 4.0 is an industrial evolution concept with four stages (it is mainly used in Europe, having its roots in Germany [7], [13], [18]). General Electric identified the following three innovation stages in industrial environments:

1-The industrial revolution, when machines and factories powered economies of scale and scope as depicted in Figure 1. This first wave essentially covers the first two industrial revolutions in the Industry 4.0 view, being mechanization and the advent of water and steam power in the first one and mass production (scale) and electricity in the second one.

2-The Internet revolution, which obviously also impacted industries such as oil and Gas, power production, railway transportation and healthcare to name a few of the industries we talk about here. This Internet revolution is essentially what some call the Internet age and others the digital age with the advent of computers and distributed information networks (from LANs, WANs and the client-server model to the “big one”, Internet).

3-The Industrial Internet, which is the third and current wave. It is somewhat comparable with the fourth industrial revolution in the Industry 4.0 model, where we mainly talk about cyber physical systems and the integration of Information Technology (IT) and Operational Technology (OT). Integration of technological bricks into processes of a production company can be defined according to the model presented in Figure 2. This representation fits on various technological barriers: scale of
maturity of available technologies and/or know-how, roadmap of appropriation. The Internet of Things (IoT) has become essential to access different services and meet requirements of the Digital Factory.

In this paper, we propose elements of response to this digital revolution with some bricks and functionalities that can be implemented as part of an Industrial Control System. Many technological solutions and technological barriers are implemented on a process. This paper is divided into five sections. In the first section, we present Industrial Internet with IoT applications. We present various works that have been carried out to validate the concept of Industry 4.0 (TIC : or a basic use of the Internet, interconnection of systems and networks, information systems. architecture that served as test support). In the second section, we present details of the global application in a SCADA (Supervisory Control and Data Acquisition.) approach. The real application that we propose is homothetic compared to the various current industrial applications. In the third section, we present access solutions to process and/or plant data on-line in “desired” time. In the fourth section, we present all the results from our study. We will conclude our presentation with a conclusion.
The Used Architecture

In our study, the controlled process is connected to the VLAN3 GEII, a subnetwork of our Backbone as it could be in a company. This VLAN interconnects three floors of the department with different rooms and different materials and processes (computers, printers, systems...). System architecture for various tests is shown in Figure 3. The room concerned integrates different equipment from different manufacturers which are interconnected by field bus (Phoenix Contact, Schneider Electric, Siemens). Many workstations are also connected on the same LAN. Automation devices are connected on a PROFINET and PROFINET IO (PROFINET IO is the evolution of the PROFIBUS DP network to an Ethernet base) network. Unlike PROFINET CBA (Component Based Automation) for distributed systems, PROFINET IO focuses on data exchange between Programmable Logic Controllers or Human Machine Interface. A PLC (Siemens-CPU: 1512C) and seven operator panels (KTP700) are interconnected (Figure 3). These panels are clients of the application hosted in the PLC associated with shared variables. This kind of architecture can be used on long production line requiring numerous operator panels so that they can control the line in all respects.

Figure 3. System architecture.

Manufacturing/Control System Integration

For requirements of world of process control, access to process and/or plant data on-line and in “desired” time is crucial. Business progression involves parallel growth of volume of process data and their translation into relevant indicators to the management teams [2], [10]. Often, those in charge of an IT system are focused on connecting and retrieving plant information [1], [12]. But frequently, these data are not efficiently and quickly used, which is essential for controlling operating costs. The work presented consists in setting up an operational structure showing foundations of a communicating industrial architecture (Figure 3.). From the information coming from the process, we want to develop and use a new several clients in a SCADA approach [5]. We show, in this paper, several solutions to implement, to perform a wide range of tests. For this, data is centralized in an OPC server and made available to different OPC clients. This architecture makes it possible to follow “on-line” several data objects.

Details of the Global Application in a SCADA Approach

The manufacturing process is controlled by a PLC. This emulates a part of process that is able to produce different recipes (Figure 3.). The interconnected operator panels are able to control and visualize the different states of the process. This kind of architecture is used in many industrial applications. There are different solutions for remote control of an operator panel (for example:
The client n°1 is a third-part solution (Cogent DataHub software) that provides many services for other potential clients/server. The Client n°2 (Excel) will develop (ongoing communication), dashboards, histograms, statistical calculations... on field data that we want to monitor. Client n°3 will offer automatic E-mail messaging services by trigger defined on field data. Finally, the Client n°4 (MATLAB) is a well-known R & D environment. It will be used to visualize process data using the OPC Toolbox.

**Software Used**

The Totally Integrated Automation Portal (TIA Portal) platform is the new work environment that enables the implementation of automation solutions with an integrated engineering system. This environment complies with the IEC 61131-3 standard [11]. All the tests carried out were conducted with version V14-SP2 (under Windows 10-Pro). Different OPC servers can be deployed and used to meet the requirements of the work presented in this article (CODRA Composer, OPC Server, Matrikon OPC, Resolvica OPC, SV OPC...). We chose to use the Cogent Data V8-2017 solution which offers a very varied service platform (Modbus, DDE, TCP, ODBC, HTTP, XML). This software is an OPC UA client for the PLC and it becomes an server for different kinds of technologies. For Client n° 2, we used the Office 365 package. Thunderbird version 45.8.0 was used for the messaging application (Client n°3). Client n°4 uses the Matlab R2016a version with the OPC toolbox.

**OLE for Process Control Unified Architecture (OPC UA)**

The aim of this study is to test various services offered by the new OPC standard: OPC UA. The latest OPC UA (Unified Architecture) specifications have been validated. With this new version, OPC UA should succeed in unifying exchanges at the level of industrial systems where the Industrial version of Ethernet has not succeeded. Standard Ethernet (802.3) could have been used as a basis for an industrial, real-time, reliable and secure fieldbus, but unfortunately the various suppliers of industrial solutions have not managed to agree on a common standard. Figure 4. (a) shows Industrial network market shares 2018 according to HMS (HMS: Since the start in 1988, HMS Industrial Networks has helped companies get connected. Three decades later, trends such as the Internet of Things and Industry 4.0 require more and more industrial machines to become networked.). Industrial Ethernet has overtaken traditional fieldbuses in terms of new installed nodes in factory automation Figure 4. (b). This is the main finding in HMS Industrial Networks’ annual study of the industrial network market. Industrial Ethernet now accounts for 52% of new installed nodes (46% last year), while fieldbuses are on 42% (48). EtherNet/IP is now the most widely installed network (with 15%), followed by PROFINET and PROFIBUS (both with 12%). Wireless technologies are also becoming a real alternative with 6% market share (Figure 4. (b)).

![Figure 4. Industrial network market shares 2018 [14].](image)

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Most of these Industrial Ethernet versions have been developed on the basis of an existing fieldbus: Profinet field network from Profibus (Siemens), Modbus TCP from Modbus (Schneider-Electric), Ethernet/IP from DeviceNet or ControlNet (Rockwell Automation) or developed as Ethercat which uses the most of Ethernet support (maximum bandwidth efficiency). As this unification of exchanges could not be done at the hardware level, OPC UA offers the opportunity to do so at the software level. The OPC standard, which appeared in the 1990’s, allowed exchanges between automated systems and supervision tools based on personal computers. The strong constraint was to rely on the proprietary protocol of Microsoft DCOM (Distributed Component Object Model. DCOM is a proprietary Microsoft technology that enables communication between distributed software components within a computer network.). OPC UA is open, platform independent, for all applications and connections. It will thus allow communication between all the elements of the different layers of the CIM (Computer Integrated Manufacturing) pyramid, from a component (for example an actuator) to the level of an ERP (Enterprise Resource Planning) [16]. It can be integrated in a powerful enterprise server as well as in a small connected object (IoT). The structure of OPC UA has been specified in several parts. For example:

- Part 1 - OPC UA Concepts: applicable to the OPC UA server and client,
- Part 2 - OPC UA Security Model: model to secure exchanges,
- Part 3 - OPC UA Address Space Model: definition of object organization. The object-oriented model was used.

Creation of the Application Hosted in the PLC (Process Brain)

The application managing the process is developed with the TIA Portal programming environment. This application is not intended to manage a complex process and a large volume of variables. The purpose of the application is to study feasibility of the approach. Nevertheless, it must make it possible to integrate concepts commonly used in an industrial application: digital and analog input-output management, management of running modes, recipe management, reporting, alarms...

The programmable logic controller (CPU 1512C-1 PN) is used in a wide array of applications: special machines, textile machines, packaging machines, machine tool manufacturing, electronics and electronics industry, automotive, environment, food industry...

Results

Server n°1: Cogent Data Hub

OPC UA is able to manage authentication and authorization of its use by different users. To establish a connection, the user can identify himself by: an X.509 certificate (X.509 is a standard specifying formats for public key certificates, certificate revocation lists, certificate attributes, and a certification path validation algorithm, defined by the International Telecommunication Union.) [3], a user name / password or Kerberos (Kerberos is a network authentication protocol that relies on a secret key mechanism (symmetric encryption) and the use of tickets, not plain passwords, thus avoiding the risk of fraudulent interception of users' passwords.) [6], [15]. This management can be configured in the PLC parameters. In our tests we do not use this option. Object linking and embedding for Process Control (OPC) is a series of standards and specifications for industrial telecommunication used for process control and reporting. There are a large number of OPC servers allowing connectivity with different PLCs, industrial PCs. Very often, manufacturers of automation hardware offer an OPC software suite compatible with their product range. This then allows supervision software vendors to create “OPC client” applications to easily access real-time data from a manufacturing process, system, and machine... With OPC UA, there is no longer a mandatory connection with a software suite attached to the hardware manufacturer. In this new software orientation, Cogent Real-Times Systems [8] proposes a software suite allowing to have very numerous services (Figure 3.). All these services will not be developed in this paper. In this work, we will develop two points: Client n°2 reporting...
based on Excel and Client n°3 messaging based on Thunderbird. In order to work with Client n°2 and Client n°3, a number of settings must first be made in Cogent DataHub. This software environment allows connection to different OPC standards: OPC UA, OPC DA, OPC A&E. Within the framework of our application the connection to the server must be done at point: opc.tcp://PLC_IP:4840 (Figure 5. (a)). As shown in Figure 5. (b), different parameters are necessary to enable connexion. The reader may refer to [4] for more details. The Connection Test section shows that the connection is correctly set Figure 5. (c).

**Figure 5. Cogent DataHub parameters.**

**Client n°2: Reporting by Excel**

The Client n°2 allows to develop man-machine interfaces with live reporting of production. This approach could be used as a component for reporting in an ERP implementation. In our case, we chose Excel but open source solution like Open Office environment is also compatible. Developing this client is an easy task. The tool provides “drag and drop” possibility: Chosing an object in the Cogent DataHub interface (drag) and put it in the cell of a table (drop) Figure 5. (f). Then, it is necessary to write some scripts (Macro) to allow graphs formatting, while respecting the sampling criteria of measurements. These criteria will depend on the production context associated with the different process time constants to be monitored. A possible formatting with results recorded during a test is proposed in Figure 6. (a) and (b). With this indicator, a production line manager could perform optimal control-command of the operation. He could collect process statistics used to optimize the Overall Equipment Effectiveness (OEE).

**Figure 6. Example of results available in Client n°2.**

**Client n°3: Messaging with Thunderbird (E-mails)**

Cogent DataHub also allows sending E-mails and text messages, triggered by an event such as a change in value on a measurement or by a time trigger (Figure 7.). E-mails and associated messages can be edited as plain text. They can contain the current values from the line production process.
Before sending an E-mail, account parameters of messaging need to be configured: SMTP server, Port, user name… Rules of crossing and security on the firewall (PIX 515) must be adopted by the person in charge of computer administration. The computer hosting Cogent Datahub needs to access to Internet but for integrity of data that can be provided, it is necessary to close all ports that not need to be used. The list of ports to be opened is related to services to be proposed.

Figure 7. E-mail configuration and results.

Figure 7. (a) shows settings to be configured in order to send messages (SMTP server, Port and sender E-mail). Figure 7. (b) shows the variable to be monitored with an associated message (Subject). Figure 7. (c) shows trigger conditions that can be set to validate the sending of the message associated with a variable. Figure 7. ((d) and (e)) shows received messages for two different triggers associated with two manufacturing recipes. The name of the recipe is indicated in the “Subject”, its validity is specified by the value 1 (message body).

Client n°4: Matlab and OPC Toolbox

The Matlab OPC Toolbox (R2016a) provides a connection to OPC DA(Data Access), OPC HAD(Historical Data Access) and OPC UA servers. This connection makes it possible to read, write and record data values from different peripherals such as distributed control-command systems, monitoring and data acquisition systems... The Client n°4 can therefore retrieve information from the production line. It will also be able to carry out many specific algorithmic treatments already implemented. Figure 8. (a) shows the steps to be followed in order to verify and validate the configuration to be adopted. We can notice that the service goes well through the Client n°4 (Cogent DataHub, Figure 8. (b)). It is possible to check all parameters when the connection is activated with the server (Figure 8. (c)). The four steps specified in Figure 8. ((b), (c), (d) and (e)), must be followed to obtain first convincing results.
As shown in Figure 8., the data namespace of the UA OPC server could then be browsed and selected (Figure 8. (d)). Then, all possibility of Matlab can be used in a command line (Figure 8. (f) and (g)). For this test, we have chosen three digital inputs (Bouton_Poussoir_x) and one analog output (speed setpoint image for the different manufacturing recipes). Figure 8. (f) shows that the first three values are zero [0] except the fourth [1]. This value concerns Red_Pushbutton state. This input stops the operation of the production line and thus the injection of all speed setpoints. Figure 8. (g) shows that the speed setpoint image is set at (16500) and confirms that the system is not stopped.

Once these data are collected, it is possible to explore the development potential of Matlab. Works applied to diagnosis and prognosis for processes or systems can be used. Indeed, measurement and data recording are the essential starting points for process or system modeling.

Conclusion
We have detailed in this article many tools capable of meeting very different and complementary needs in the implementation of digital solutions for industrial or tertiary processes. Cogent DataHub offers many possibilities. We have shown some reporting features that can be implemented on a production line in SCADA approach. We showed that Excel software can be used quickly to isolate some relevant indicators. These indicators can then be followed live. We also showed that the E-mails function can allow a good efficiency in the management of particular alarms. In our case, we have validated this strategy, but it is also possible to activate specific messages for Short Message Service for SmartPhone technology. Finally, we validate the repatriation of data under Matlab. This validation opens other doors in data processing for datamining, system maintenance, diagnostics... These digital technologies are profoundly modifying the uses that seem limitless except, those of imagination and the inventive power of new actors!

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