From ISA 88/95 Meta-Models to an OPC UA-Based Development Tool for CPPS under IEC 61499

Marcelo V. García, Edurne Irisarri, Federico Pérez, Marga Marcos
University of the Basque Country, UPV/EHU
48013, Bilbao, Spain
{mgarcia294, edurne.irisarri, federico.perez, marga.marcos}@ehu.eus

Elisabet Estevez
University of Jaen
23071, Jaén, Spain
eestevez@ujaen.es

***Abstract*— In the era of Industry 4.0, fast-growing requirements for an agile and effective vertical integration are challenging the smart manufacturing. Cyber-Physical Production System (CPPS) technology plays a key role in the Industry 4.0 factory. One of the reasons for this is that shop floor data collection, monitoring and processing are enabled by CPPS devices together with IEC 61499 standard. To this end modeling and developing software and hardware components focused on distributed control systems are provided. This improvement in data monitoring and processing results not only in an optimization of equipment predictive maintenance but also in the ability to integrate new control techniques. This approach provides the Oil&Gas industry with the foundation to transform their traditional production fields into Intelligent Oil Field (IOF) environments. The aim of this paper is to build bridges between the state of technology and the design of industrial control applications. In particular, a CPPS platform developed through a software engineering tool giving support to the design of applications is proposed. It is based on the IEC 61499 and on a configurable OPC-UA server that maps field device data into an ISA95/88-based information model. Thus, this proposal will not only save Oil&Gas engineer time, it also will save efforts of adopting this promising technology.**

Keywords—OPC UA; ISA 95/88; IEC 61499; Vertical Integration, Intelligent Oil Field

I. Introduction

Over the last years we are witnessing a dramatic decline in petroleum production rates. This has driven a sharp fall of oil prices, as long as the costs of extraction and other operations remain unchanged. Facing this new situation, companies of crude exploration and production around the world are committed to work for digitizing industry, as a major step towards a higher efficiency. In this context, the new Intelligent Oil Field (IOF) concept has been developed by researchers and oil companies. The IOF provides oil workers and engineers with the ability to visualize key data proceeding from all operations, such as the ones related to the assets, measurements or documents. These data are enabled to be accessed in real time by means of consistent and intuitive formats. In fact, this information performs a comprehensive and unified view on which the different stakeholders could base their decision-making process.

This emerging vision of the IOF can now be achieved within the new environment promoted by Industry 4.0 approach, as discussed in [1]. In fact, both Industry 4.0 and IOF enable production optimization across sites, support inter/intra-site regulatory compliance, and enable collaborative manufacturing performance management. This approach makes possible to establish relations among different equipment and to track events and conditions happening on multiple locations.

Cyber-Physical Production System (CPPS) is one of the key enabling technologies on which Industry 4.0 is based. A CPPS provides the ability to directly collect and to evaluate process data in real time. Thus, it facilitates an integration of the physical world with the digital world [2]. This is a concept that is widely used in the Oil & Gas industry and IOF environment.

On top of that, the IEC 61499 standard provides a development framework based on models for distributed control systems. In this sense, within the IOF vision, CPPS devices along with IEC 61499 will supply appropriated software and hardware components for modeling and implementing. As a result, communications will be improved and other operations such as key data collection, reporting, monitoring, and information sharing will be enabled. CPPS technology is intended to help decision-making in companies, leading to undertake appropriate actions based on more informed decisions, when required and in real time.

However, within an IOF approach a protocol enabling data collection and connectivity –without rip-and-replace updates of existing systems– is required. To this end, the OPC-UA (IEC 62541) standard could be a promising alternative since it is based on a service-oriented architecture, in which not only data security but also reliable information models are provided. [2]

OPC-UA defines configuration files for the servers in charge of data integration at plant level. These files must fit both plant models and models of the data-providing devices. Among most widely used industry standards, ISA95 (IEC 62264) [3] and the physical model of ISA88 (IEC 61512) could be mentioned. These standards define a hierarchic model where the equipment's role in the production processes is well described [4].

The goal of this paper is to propose a software tool aimed at supporting the design of distributed control applications within the IOF vision. It is based on the OPC UA and the IEC 61499 standards. In particular, the information required to connect the distributed components of the application is captured so that the ISA 88/95 based information model of the whole system could be generated.

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The layout of this paper is as follows: Section II shows some related works that have been used as the starting point for this research. State of Art is shown in Section III. Section IV introduces the general scenario. The ISA 88/95 meta-models defined for oil production process are illustrated in Section V. Section VI describes a proposal to implement a CPPS, using IEC-61499 and OPC UA server, modelled under ISA 88/95. This section also describes the implementation of an engineering tool that assists the creation of configuration files for IEC 61499 applications, making use of SIFBs. Section VII shows a case study in which Information Components, making use of OPC UA servers, are implemented for Petroamazonas EP Petroleum Company. Finally, some conclusions and ongoing works are drawn in Section VIII.

II. Literature Review

The aim of this section is to show how other researches deal with the design of 61499 applications in CPPS systems using OPC UA or ISA 95/88 for vertical integration. In this sense, a set of related works are presented, paradigms and development technologies, which provide service-oriented architectures and CPPS systems.

As defined in the Industry 4.0, smart, reliable and autonomous solutions are required to support the CPPS implementation process [4], [5]. The CPPS design and its deployment in the industrial domain is the main aspect of the 4th industrial revolution as a concept that will enable the interconnection of heterogeneous and remote systems. This can be feasible within the implementation of the service-oriented architecture paradigm, the employment of Information and Communications Technologies (ICT) based solutions and the realization of Industrial Internet of Things (IIoT). In this situation, some researches [6], [7] have been performed before this work in order to prove some of the concepts that such kind of systems implementation requires.

In this sense, an approach, based on the combination of embedded systems, is introduced by eScop European project [8] This work presents an ontology-based knowledge management and service-oriented architecture for integration of shop floor in MES. Delsing et al. [9] introduce a migration approach from legacy industrial process monitoring and control systems to a SOA-based process monitoring and control systems by addressing a SOA-based interface between hardware and software systems. In this paper an IIoT approach to implement the same middleware concept using IEC 61499 and OPC UA mechanism is addressed.

The idea of integrating the plant floor systems of manufacturing with business systems has already been faced from several research projects. The technologies applied in them could be considered quite similar to the ones proposed in this study. However, exactly the same combination of technologies, i.e. combination of OPC UA with IEC 61499 and ISA-88/95 standards has not yet been reported. In Virta et al [10] design and implementation of batch scheduling and material reporting interface between MES and Basic Process Control System (BPCS) is proposed. The data exchange between the ERP, MES and BPCS are implemented with SQL tables. In this research OPC UA or IEC 61499 are not used as a vertical integration mechanism.

In summary, these research works share the goal of searching novel techniques and methodologies to develop distributed industrial systems, mainly under ISA 88/95, but they do not focus on integration through a useful communication protocol in smart factories, such as OPC UA and IEC 61499 automation distributed standard.

With the purpose of implementing the distributed control approach in industrial systems, event-driven function blocks have been developed and implemented according to the IEC 61499 standard. The IEC 61499 function blocks present an extended version of the function blocks based on the third part of IEC 61131. Among the commercial tools used to develop control applications with the IEC 61499 standard, the following could be the most widely used in the industrial environment: Functional Block Development Kit (FDBK) [11], originated from the HMS project [12], ISaGraph [13], ntxControl [14] and 4DIAC [15]. To ensure the applicability of IEC 61499 standard in diverse hardware devices, the device manufacturers should develop technical support according to the standard.

But so far, the research about IEC-61499 has only been focused on discrete control processes. This paper goes one step further in the use of IEC 61499 to monitoring analog processes and performing a plant floor integration using industrial communications protocols.

Finally a research work by Kozar et al [16] introduces an approach that integrates 4DIAC platform with OPC UA communication protocol and aims at providing their seamless integration making use of OPC UA concepts. As well as that, it integrates the knowledge on the application structure by means of the information model of OPC UA. Thus, additional input from the developer of the system is not required. However, this one and other researches undertaken by the authors [17], [18] go further defining the integration between an OPC-UA server and some industrial communication protocols such as Modbus/TCP, TCP/IP, S7 protocol, etc. This way, the field data in automation systems could be accessed through OPC UA servers in a low-cost CPPS architecture.

In this paper the integration of an SIFB OPC-UA server and IEC 61499, with Address Space modeled according ISA 95/88, is addressed. Furthermore, this paper develops a new software tool based on XML, enabling an easy and fast building of this kind of automation systems

III. State of the Art

A. *IEC 61499 Standard*

One of the main goals of IEC 61499 is to promote the development of heterogeneous systems composed of control devices from different manufacturers. In particular, the goal is to allow a dynamic reconfiguration, that is, to change the system´s configuration while the control application keeps running.

IEC 61499 represents the next generation of standards in automation systems and it is designed to ensure the

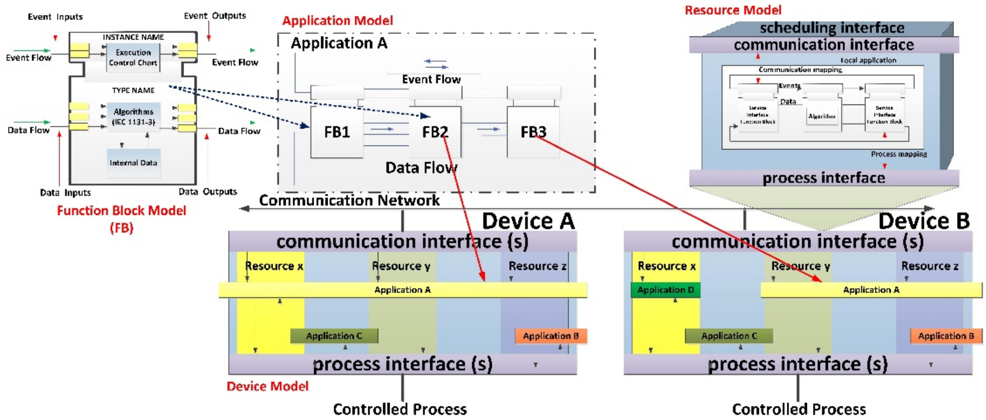

Fig. 1. IEC 61499 Architecture Models

interoperability, portability and reconfigurability. These aims are not considered by the IEC 61131-3 standard

IEC 61499 defines a generic and hierarchic architecture of models, allowing a system and its components' organization. It develops a new structure for distributed control applications. The models are generic, independent from the domain and extensible with the definition and use of FBs (see Fig. 1.): Functional Block Model (FB), Resources Model, Device Model, System Model, Application Model, Distribution Model and Management Model. [19]

FB model is the primary and elementary model of the standard. FB is a functional unit, which has input/output events. As well as input/output data it has algorithms which are transparent to the user. FBs-based architecture for control devices enables a modular design approach and makes the development process easier and more efficient. However, since the IEC 61499 is a conceptual reference model for general purposes, it is necessary to establish a model derived class FBs for a particular application from an object-oriented view.

B. *OPC UA*

The most recent supervision and management tools of manufacturing processes need to collect information, in real time, from production assets which are usually driven by controllers from different manufacturers.

The Unified Architecture UA, proposed by OPC Foundation, is capable of responding to the current issues concerning the following aspects: 1) data integration at plant level regarding how to locate a speaker in a communication; 2) how to identify data, metadata and control logic metadata; 3) how to define the information that must be visible for other devices. Nevertheless, all criteria regarding the data integration problems at plant level should be taken into account for guaranteeing a successful information exchange between the different manufacturers [16].

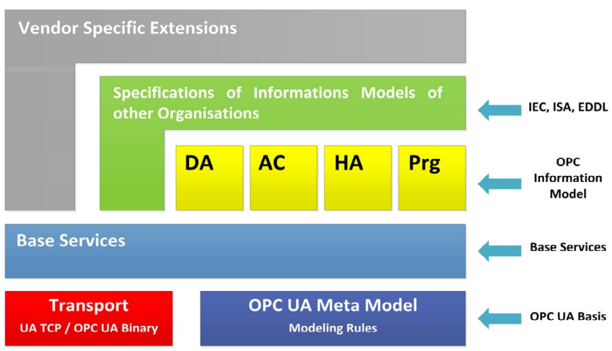

Fig. 2.. Information Model Layer of OPC UA

OPC-UA additionally defines a set of abstract services that can be executed in different communication infrastructures and its meta-model is the foundation to define the adequate parameters for the services. The basic OPC-UA model of information provides the essential object types and the access points to the address space in the server. Using the basic information model, it is possible to establish normalized information models or provider-specific models. [20]

OPC-UA already defines many normalized information models for data access, alarms and constraints, programs, historic data and added functions. This is shown in Fig. 2. OPC-UA also has the mechanisms for supporting multiple information models in a server. This guarantees a high level of interoperability due to the fact that not only data can be simply changed between devices but also the semantics can be defined clearly.

C. *ISA 88/95 Standard*

ISA 95 is the international standard for integrating enterprises management systems and industrial control and automation systems. It was developed by ISA, in 1990, for reducing risk, cost and errors that came along with the implementation of interfaces between enterprise systems and control systems. At present it is accepted as IEC 62264 standard.

ISA 95 provides a hierarchical organization of the production system, including all production levels, from the physical processes –which can be batch, continuous or discrete process– up to the ones on the highest level called Business operations [3].

A standard that complements ISA 95 is the ISA 88, which first aim is to offer a methodology for enterprises having batch manufacturing processes. ISA 88 allows the industry to design models for production automation and, at the same time, to reduce complexity and costs related to proprietary systems.

Even though it was initially conceived only for batch production, at present it can be used in continuous and discrete processes too.

To carry out an industrial control process ISA 88 standard indicates that the plant equipment´s capacity (physical model) and the required control procedures called recipes must be analyzed separately. In this sense, this standard aims to optimize the use of the installed capacity in the plant and to have more flexibility when modifying control algorithms.

IV. General Scenario

The architecture on which this paper is based has been previously presented in [21]. Fig. 3 depicts the general scenario for the monitoring process. This architecture is composed of a set of components that manage a set of models representing the physical world, the information exchange as well as the information to be accessed.

The physical world, understood as the production process is called *Production Process Model* (PPM). This model is composed of the accessible data, generated in the production process (data source), and also of the intelligent devices belonging to the plant that are responsible for communicating the actual data values (data suppliers), is specified from two points of view following the ISA 88/95 standards

First point of view of physical plant, including the accessible process variables, is defined by means of the so-called *Plant Topology Model* (PTM). This model collects the physical components of the plant. Second ISA 95/88 point of view is about the data supplier devices, being process controllers and / or smart devices offering process data and their characteristics are defined in the so-called *Plant Intelligent Devices Model* (PIDM).

The architecture also defines other two models: (i) The user requirements for monitoring and it is the responsible for accessing the appropriated data process devices is processes by the *Information Exchange Model* (IEM). (ii) The last model is called *Plant Information Model* (PIM), corresponds to the user monitoring requirements which can be defined from the PTM specifying the process variables as well as the type of access. This information is structured in the so-called Information Components (IC). ICs are the mechanisms to access the plant data

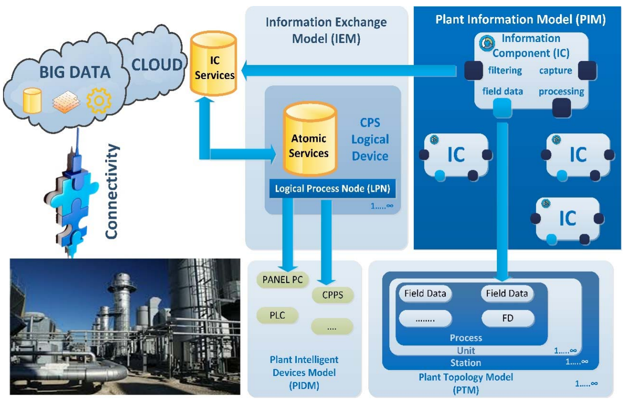

Fig. 3. General Scenario for the monitoring process

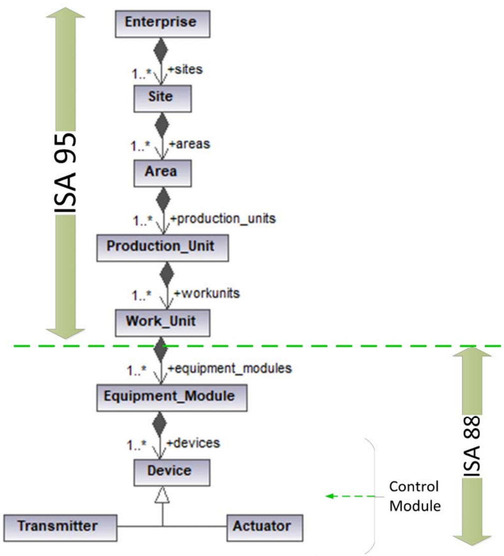

Fig. 4. Plant Topology Meta-Model lexicon and syntax

V. OPC UA Address Space Process Meta-Model based on ISA 88/95

The Address Space *Process Meta-Model* is formed by two main parts: *PTM Meta-Model* defines the physical components of the *production* plant, i.e., the set of production processes that group the accessible data from each process. It should be at the same time generic enough to describe any production process and able to be customized to the specificities of a particular enterprise. Physical process variables are characterized by their properties (such as physical magnitude, engineering units or range of possible values, among others). On the other hand ,the *PIDM Meta-Model* describes the devices (e.g. process controllers or smart devices) with processing capabilities that can play the role of data suppliers within the architecture. The following sub-sections describe the corresponding meta-models which conform to ISA95 and ISA88 standards fitting the specificities of oil production industry.

A. Plant Topology Meta- Model (PTM)

Proposed Meta-Model for the PTM is shown Fig. 4. The ISA95 and physical model of ISA88 propose a hierarchy model for characterizing the role of the equipment for production processes. From them, the following ones have been customized to continuous process of the oil production field:

- ***Enterprise***. The enterprise is responsible for determining what products will be manufactured. For production field it is considered as *Company*.
- ***Site***. A geographical location and main production capability usually identifies a site. A group of sites determine an enterprise. This concept is represented as *Block*.
- ***Area***. The main production capability and geographical location within a site usually identify areas. Areas generally have well-defined manufacturing capabilities and capacities. Many areas will have a combination of *production lines* for the

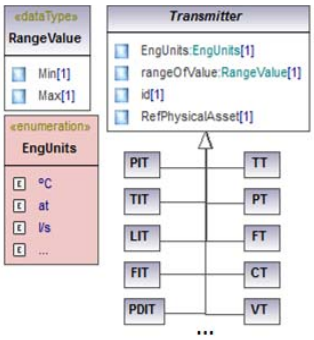

Fig. 5. Characterization of Transmitters

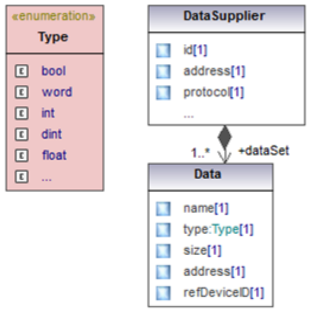

Fig. 6. Minimal meta-model for intelligent devices with data suppliers issues

discrete operations, *production units* for the continuous processes, and *process cells* for batch processes.

- ***Production Unit (PU)***. A production unit generally encompasses all of the equipment required for a segment of continuous production that operates in a relatively autonomous manner.
- ***Work Unit (WU)***. It identifies the major processing capability of family of products. WUs are the lowest level of equipment typically scheduled by the Level 4 and Level 3 functions for batch manufacturing processes.
- ***Equipment Module (EM)***. Physically, the equipment module may be made up of control modules and subordinate equipment modules. An equipment combines all necessary physical processing and control equipment required to perform those activities.
- ***Control Module (CM)***. A control module is typically a collection of sensors, actuators, other control modules, and associated processing equipment that, from the point of view of control, is operated as a single entity. Fig. 5 illustrates the main characteristics of Transmitters which are characterized by an identifier, range of values, engineering units and the serial number of the corresponding physical asset.

B. *Plant Intelligent Device Meta-Model (PIDM)*

The devices that act as data suppliers are characterized by the information needed to access the process data they provide. They range from PLCs, DCS, embedded systems, industrial controllers, smart sensors or any other device that can access process variables. Hence, the equipment model proposed by ISA95 standard has been used for its definition.

Properties of every Data Supplier are those that specify the communication with other devices and the process data they offer. Fig. 6 highlights those properties.

VI. Implementation Approach

A. *Definitions of Modeling Language*

In this section, the focuses are the meta-model of the engineering tool, defining a specific modeling language, giving support to the communication model and runtime environment. Then, this research makes use of these achievements to construct a proof-of-concept M2M kernel enabling basic shop floor communication based on OPC UA and ISA 88/95 standards.

Firstly, the authors explore the model-based design approach to create runtime applications according to the IEC

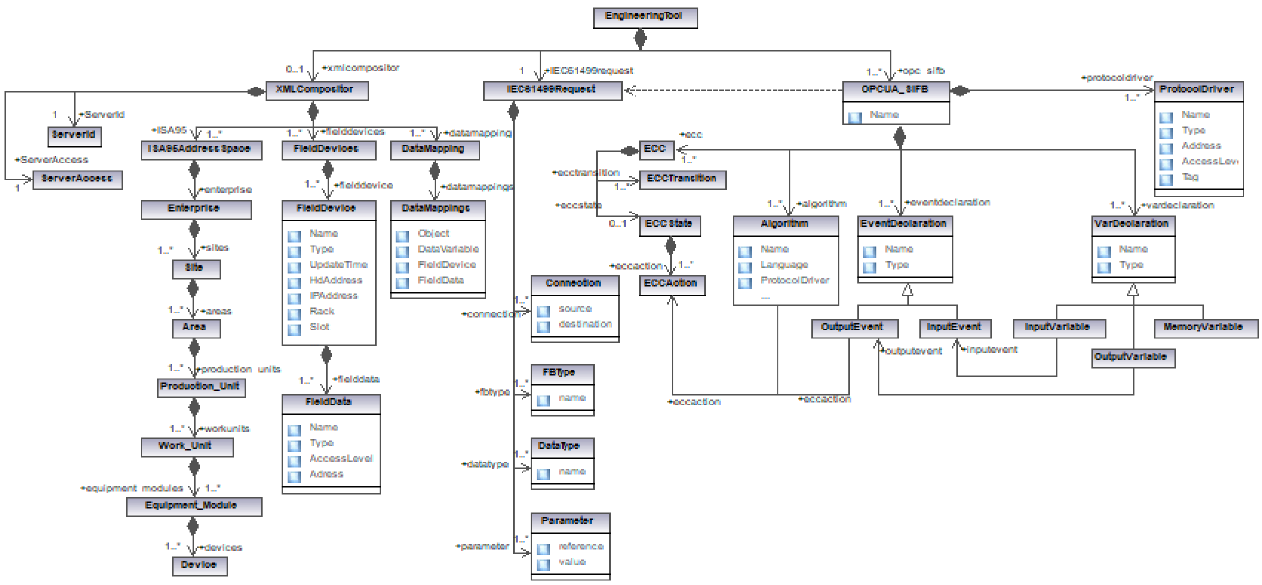

Fig. 7. DSML Meta-Model Proposed

61499 standard and using Compliance Profile for Feasibility Demonstrations (CPFD or IEC 61499-4). Application of CPFD requires to consider on both design layer and execution layer. In the design phase, developers construct logics and functions of the software system by means of domain-specific models. The built system model can be translated into analyzable input models of other verification tools to find out design issues and system defects in early stage. Therefore, modeling language tailored to M2M domain should be defined to facilitate such a model-based development process. Structural and behavioral abstractions are the primary tasks during the specification of a Domain-Specific Modeling Language (DSML) since they are corresponding to the syntactic and semantic definitions, respectively.

The root element in the DSML definitions is the system model, as shown in Fig. 7. The system model is composed of OPC UA server SIFB model, XML Configuration file compositor and Request communication model and the relations between these models. Such definitions are compliant with the IEC 61499 standard.

The engineering tool system model can contain multiple OPC UA server SIFB models and Field Device models. The OPC UA server SIFB model is the extension of the IEC 61499 standard for describing communication process and for integrating data using industrial protocol drivers during the design process. The SIFBs and related connections will be allocated to specific tasks, as defined in the configuration model. Some constraints are simply defined as attributes of the models, such as the industrial communication drivers for tasks (type, execution time download, update time, etc.), while more complicated requirements can be specified with the atom called constraints in Fig. 7.

XML Compositor has classes like: Address Space under ISA 88/95 model, Field device models, and Data Mapping models. This module creates an XML file configuration for OPC UA server including all essential parameters such as URL address, vendor name, server name, version, etc.

B. Software framework design for developing OPC UA server using ISA 88/95 meta-model and IEC 61499 configuration files

The aim of this section is to present an open source Integrated Development Environment (IDE) as a tool to be used as reference in the industry, according to the IEC 61499 standard. Its application in many industrial automation domains is also analyzed. To this end, Information Components (ICs) are developed making use of CPPS architecture, as previously mentioned, and OPC-UA as communication protocol. Regarding OPC-UA communication technology, the Address Space model is based on ISA 88/95 standards through PTM and PIDM meta-models. This approach provides the Oil&Gas engineers with the ability to include this standard in their industry facilities.

A general view is depicted in Fig. 8. It represents the elements needed by the tool to perform the composition mechanisms. It is a platform-independent application which receives as entry the above mentioned system model, based on XML and retrieves a complete application including the SIFBs of the corresponding OPC-UA servers automatically, generating a new system document.

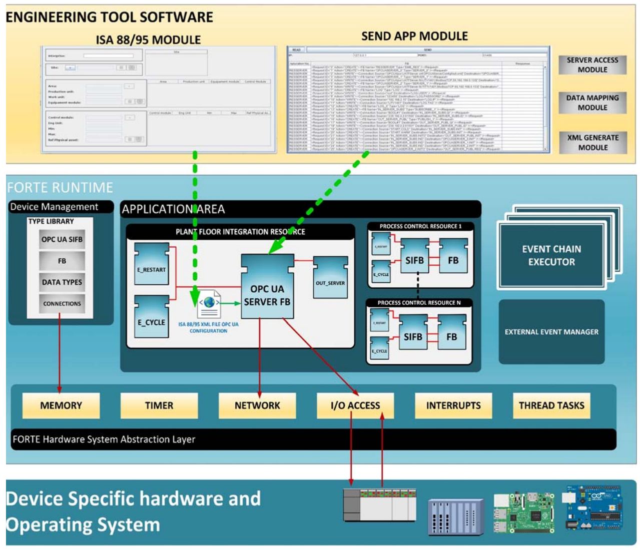

Fig. 8. Engineering Tool Application framework

The engineering tool designs and generates the following files: (i) The static configuration document for vertical integration of the plant using PTM and PIDM models, which contains information in XML format, of the application. (ii) The SIFBs library containing information of the SIFBs of communication servers with OPC-UA protocol. This tool is mainly charged of including the SIFBs, the connections and the necessary configuration data for the corresponding devices aiming at the distribution of the application automatically.

An engineering tool has been designed based on Java software. This tool has functions which are described below (see Fig. 8):

- SERVER ACCESS: this element provides the OPC UA server access with a name, an URL, an URI and a path.
- ISA 88/95 MODULE: this element groups the definition of the nearby devices accessible by the server in the system involved in the automation system. This section includes the OPC-UA nodes under ISA 88/95 standard following meta-models of PTM (node types and node instances).
- PIDM MODULE: this element defines the existing relationships between Data Variables of the EMs declared in the ISA 88/95 section, and the Data Suppliers. As a result of these three sections a XML File configuration following meta-model of PTM and PIDM is created and downloaded
- GENERATE: it creates and shows an XML file whose one part is to create the OPC UA SIFBs and another one to connect them allowing the FORTE runtime to understand the instructions and to create the data acquisition application.
- SEND: it allows for downloading the generated XML files on the CPPS device. At this point an IP address and the communication port are required to start the download.

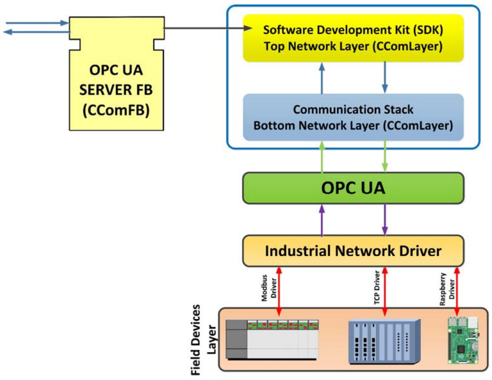

Fig. 9. Application Architecture for OPC UA Implementation

C. SIFB STATIC OPCUA_SERVER

This SIFB aims to implement OPC UA servers, which have subscription mechanisms. The 4DIAC-IDE framework is used for the design of the SIFBs which are implemented using the runtime DIAC-FORTE.

This SIFB provides OPC UA communication using FORTE. The network interface is designed to be as flexible as possible. The basis for the network interface is the implementation of the layer design pattern to communicate with the communication stack made in C++. This stack is used to integrate OPC UA into FORTE, which is fully scalable, supports multi-threaded architecture, being every connection or session operated by separate threads. This SIFB is previously presented in [17], [18], [22] papers. The architecture overview of this implementation is shown in Fig. 9. The figure shows the different class types and the basic interaction with each other. The function block class (CCommFB) is the only class which interacts with IEC 61499 applications, and has to be able to send and receive IEC 61499 events.

The first part of the OPC UA server is the raw data driver component, which reads and imports raw data from physical layer devices into the stack communication layer via different drivers of industrial protocols, e.g., Modbus, TCP/IP, S7 communications. The second part is a OPC UA server component, which adds ISA 88/95 Meta-Model semantics to the imported raw data items. This SIFB allows configuring the OPC UA server through a XML file that is created by Engineering tool developed in the previous section.

Common events like INIT, REQ, INITO and CNF (see Fig. 10) are considered by SIFB as well as the following input and output data:

- <u>QI (BOOL):</u> This input data works jointly with INIT to start-up or shut-down the OPC UA server. On INIT event, if QI is TRUE, OPC UA server starts; otherwise, if QI is FALSE, OPC UA server shutdowns.

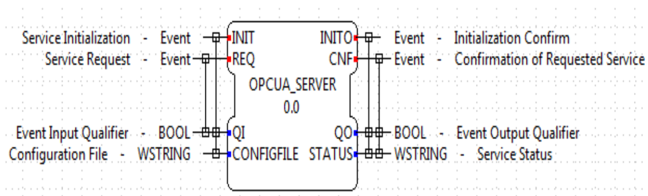

Fig. 10. SIFB STATIC OPCUA_SERVER

- <u>CONFIGFILE (WSTRING):</u> This input data holds the XML configuration filename.
- <u>QO (BOOL):</u> It informs about the performance of last procedure executed.
- <u>STATUS (STRING):</u> It reports status information of the server.

VII. CASE STUDY: PETROAMAZONAS EP

This case study was presented previously in [23]. Within oil production field, companies are commonly geographically distributed over the country; consequently, remote access to the process is of vital importance to monitor the whole process or make decisions that can affect different sites. In fact, oil production companies are usually composed of multiple blocks where production surface primary is called Oil Well-pad is a location which houses the wellheads for a number of horizontally drilled wells. Concretely, crude oil is extracted from the bottom of the wells by pumping and once on the surface it is delivered to the Central Production Facilities (CPF).

The CPF is composed of a tank called crude oil Separator, which is a pressure vessel used for separating well fluids produced from oil and gas wells into gaseous and liquid components that collects the crude provided by all wellpads of the block.

The case study is focused on Petroamazonas EP Oil Company of Ecuador. Concretely, the Block18. In this Block, there are 4 wellpads which are made up by 30 wells. The example is only focused on the oil crude separator (V-1401 of Fig. 11). This process device has been enriched with the following process instrumentation: *i*) three level transmitters LIT-V1401-01 for petroleum level, LIT-1401-02 for production water level and LIT-1401-03 for gas level. *ii*) As in the previous step, each separation line of V-1401 oil crude separator has a pressure transmitter PIT-V1401-01, PIT-V1401-02 and PIT-V1401-03 for oil crude, production water and gas pressure. *iii*) Finally, in this study case we consider three temperature transmitters for each line TIT-V1401-01, TIT-V1401-02 and TIT-V1401-03. There is also a production emergency valve (SDV-V1401-01).

Using the engineering tool, it is possible to create a XML file to configure OPC UA server under ISA 88/95. For this oil production study case the Company is Petroamazonas EP. Next step is establishing the Site in this case is Block 18. Area section will be presented as a Central Production Facilities (CPF). Hence, for Oil Production there will be two related production units: The Extraction WellPad and Oil Crude Separation. For instance, every extraction wellpad Production Unit is characterized by two type of WUs: (1) Wells from which the oil is extracted and (2) pipe layout (manifold) for routing the oil to oil crude separation PU. The Oil Crude Separation Production Unit is formed by five Work Units (Separation, Gas, Water, Oil and Draining. Control Module is all transmitters and actuators described in the previous section. The XML file configuration is depicted in Fig. 11.

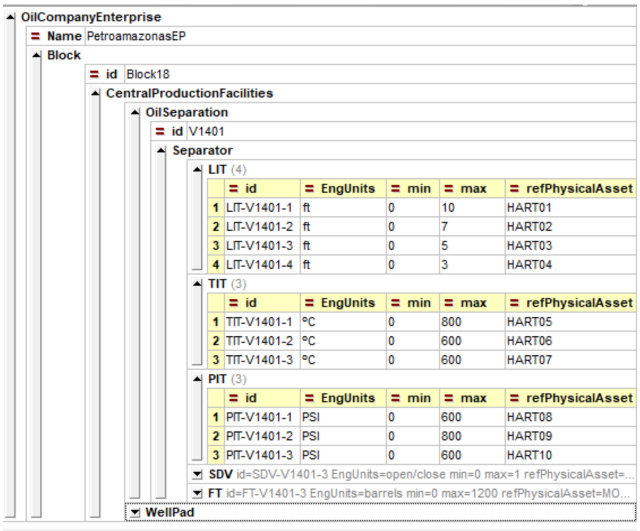

Fig. 11: Plant Topology Model (PTM) example

The second goal of this study case is to use the engineering tool to create new OPC UA servers, the data variables are the instrumentation installed on V-1401 oil crude separator. The architecture of the industrial communication system is shown in Fig. 12. We can see in this architecture that a CPPS device is connected to the TCP/IP network, on this device an OPC UA server are embedded and can access the process data given by DELTAV Controller using the drivers implemented in OPC UA server for this protocol. Once the new ICs of the process are created using OPC UA SERVER the configuration file is generated by engineering tool and downloaded to the CPPS. These variables will be available to be discovered or send to OPC UA Clients in others wellpads in an easy and secure way

VIII. CONCLUSIONS AND ONGOING WORK

This work presents an approach to access field data in automation systems. It makes use of a Java based Engineering Tool that assists in the creation, in a simple way, of OPC UA servers in a CPPS architecture. It is based on ISA 88/95 and IEC 61499 applications running over FORTE runtime. The use of this kind of systems facilitates the introduction of CPPS emerging technology within the paradigm of Industry 4.0. The proposal is specifically focused on the Oil&Gas production domain. Furthermore, an M2M infrastructure for plant floor communications is provided by this architecture.

The IDE environment will facilitate the industry of creating control applications and industrial communications required for vertical integration of data at plant level. The introduction of OPC-UA as a general and universal communication protocol contributes to a higher flexibility of the IEC 61499 standard and to finding more processes in which to be used. The proposal is especially based on the information model under the ISA 95/88 standards of OPC-UA servers. One of the advantages of it is not only that data storing is allowed but also that the storing is based on a structured network of interconnected nodes.

The benefits of using the proposed IDE in CPPS designing are plentiful. The most important, yet simplest of all, may be the ability to apply the same IEC 61499 configuration file to different processes through software reconfiguration. Points to be highlighted are also the possibility to add, remove and replace functions of an IC in a communication service for future requirements. Finally, it should also be stressed that the proposal offers simplicity due to the ability to make use of reusable software components to build new systems.

In the context of modeling industrial systems and applications, future works will include the integration of AutomationML format. The reason of that is to ensure the interoperability among the different engineering tools taking part in the process operations.

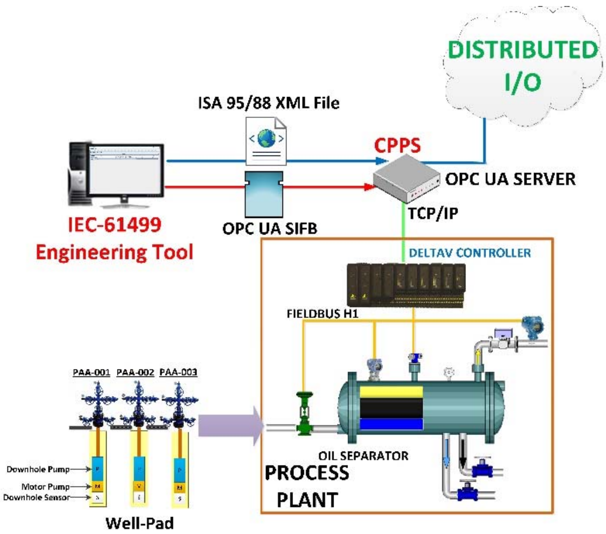

Fig. 12: Communication Architecture for Oil Crude Separator

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