Modeling and Simulation of Integration of Internet of Things and Manufacturing Industry 4.0

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Abstract. Internet of Things (IoT) is changing the processes in the manufacturing industry. It is creating new opportunities for both economies and society. The deployment of Internet of Things for the development of Industry 4.0 improves processes and manufacturing systems. In this type of systems, the information is related to the manufacturing status, trends in energy consumption by machinery, material logistics, customer orders, supply data and all data related to smart devices implemented in the processes. This paper describes an Internet of Things architecture applied to industry, a metamodel of integration in its phase II (Internet of things, social networks, cloud and industry 4.0) for the generation of applications for Industry 4.0.

Keywords: Industry 4.0 · Simulation · Manufacturing

1 Introduction

IoT has reached so much development and importance that several reports foresee it as one of the technologies of higher impact until 2025 [1]. Thousands of millions of physical elements and objects will be equipped with different types of sensors and actuators, all of them connected in real time to internet through heterogeneous networks. This will generate high amounts of data flows that have to be stored, processed and shown to be interpreted in an efficient and easy manner. Here is where IoT and Cloud computing integration permits that this huge amount of data can be stored in internet, keeping resources, services and data available and ready to use and for end-to-end service providing [2] both in the business and in the consumer field, from anywhere. It provides the virtual integration infrastructure for storage devices, analysis tools, monitoring and platform. Most interactions in internet are human-to-human (H2H).

The Internet of Things counts on sensors or scattered objects to generate information from any accessible site or inside a machine. Thus, it requires the interconnection of these heterogeneous objects via the Internet. This will lead to a future in which it is not only used for communication between people, but also between human

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and machine, and even between different machines (M2M) [3]. Here is found the importance of Smart Objects: physical objects with an embedded system that allows information processing and communication with other devices, and also the processes based on a certain action or event. However, all of these complex systems present a problem when connecting the Smart Objects due to the differences between software and hardware used for each process.

Due to the enlargement of the IoT and the Cloud Computing application development, technological problems decrease and an expansion of services is created in an industrial context [4]. This paper outlines the need to integrate the IoT, sensors, actuators, social networks and computing in the cloud. It will enable to build the Industrial Internet of Things (IIoT) up. This article describes the conceptual characteristics of the elements to be taken into account in the integration proposal and presents the integration metamodel in its phase II.

2 State of the Art

2.1 Internet of Things

Internet of Things aims to connect millions of objects of any type to Internet. It will lead to potential great changes in our lives, providing a greater productivity, bettering our health, improving efficiency, reducing energy consumption and making comfortable our houses. These may be, as already proven in some researches such as the Arduino microcontrollers, microcomputers such as the Raspberry Pi, fridges, smartphones, sensors, actuators, Smart TVs, cars, smart tags as RFID, NFC and barcodes, QR (Quick Response Code, QR Code) codes, among many other types of objects.

IoT applications currently focus on the Smart Home, industry 4.0, so-called Industrial IoT (IIoT), municipalities or villages grouped in the concept Smart Town, cities also called Smart Cities [5] and the environment that sits under the concept Smart Earth. Each of these divisions has its own applications, although all are based on IoT. Smart homes seek to prioritize automation, industry to improve the manufacturing processes, towns and villages to preserve their cultural identity, the cities their livability and environmental communication with buildings and nature. Based on this, the purpose is to create a smart world, leading to the Smart World [6].

2.2 Cloud Computing

The use the cloud, has permitted to perform all the computing in it, without any need of own servers or mainframes. This has opened a new economic model in computing, the companies offer hardware, platforms and software as subscription services. They are housed in the cloud. All is packaged and on-demand, normally over the Internet. The services that are in the cloud can be managed, either to resupply them, modify them or release them with minimal effort thanks to the tools provided by the suppliers of such services. In addition, the services are offered in a robust, reliable and available way anytime and anywhere. Hence, the three basic components of Cloud Computing are the virtualization, the multi-tenancy and the web services [2].

2.3 Industrial Internet of Things: Industry 4.0

Industrial Internet of Things (IIoT), also known as industry 4.0, is the combination of Internet of Things with manufacturing. As an emerging technology is expected that IoT offers solutions to transform transportation and manufacturing systems, improving them to obtain greater efficiency, cost savings and time reduction in processes [7].

Industrial Internet of Things (IIoT) is connecting the machines together and with the physical world of sensors, increasingly more ubiquitous, increasing the speed of business and of industrial development exponentially. The IIoT goes beyond the M2M communication [8]. It includes the connection of industrial networks and service networks to different information storage infrastructure through the provision of software services and its autonomous control in the cloud. The Industrial Internet of Things is the new industrial revolution and the rise in the use of sensors, advanced data analysis and smart decision making is changing the world itself.

The continuous technological advances have enabled the development of new methods of communication between people and objects [9], which allow the exchange of information within the parameters of speed and security. Internet of them things has exploited these advances technological and the inclusion of new elements within them systems of information to allow the access remote and the control of the different systems. This technology is used to improve the efficiency of supply chains [10] and to improve the information obtained in real time throughout the process.

There is a large number of applications in the IIoT. Proof of it is a system to locate and monitor the transport [11], allowing to predict its future location and what traffic will be on the road. However, the main application of IIoT is in supply chains where RFID technology with greater intensity is used. Exactly because IoT has an important role in the logistics industries.

3 Metamodel of Integration

Here is shown the proposal for the creation of a system that generates applications for the industry 4.0 on various platforms or operating systems. They permits to connect objects of the Internet of Things through different networks, social networks included.

While defining a device, certain features of that device and the objects that it contains (sensors, actuators) must be defined as well. The device can include rules that grants some level of intelligence, unrelated to smart objects [12].

The system was designed applying MDE, which led to a flow of steps. First of all, is needed to define the problem domain to be resolved and which narrows the field of knowledge. In this proposal, the domain is the definition of devices that may connect to the different networks either for publishing data from its sensors or for control of their actuators by other users or devices that make use of the rules that allow to automate the processes.

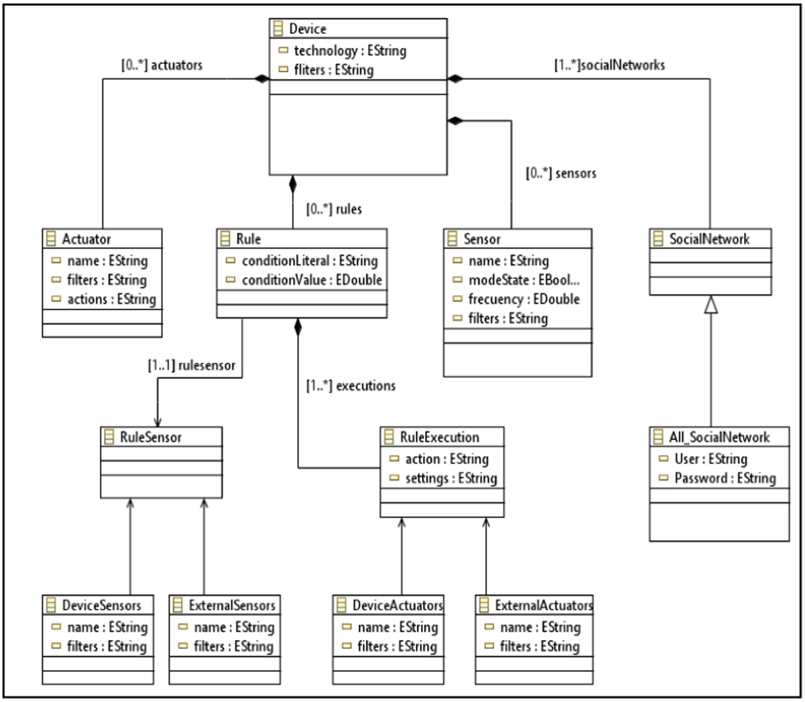

Fig. 1. Metamodel of the system. Phase I

Once the domain is bounded, the metamodel must be defined from a meta-metamodel, in this case Ecore (from Eclipse Foundation) (Fig. 1).

- The device: It is the main component and its definition is the target of the language. Its features are the technology that represents the device platform, in this particular case it is a Raspberry Pi, platform developed in one of the languages supported by Raspberry Pi; and the filters that represent the keywords necessary to identify the devices in the social networks. The device is shaped by other components: social networks, actuators, sensors and rules.
- Social Network (Social Internet of Things): A device may be associated to one or more social networks, at least one. Social networks are abstract components that another component must implement. I.e. a device can have social networks with different properties. However, all of them are social networks.
- Actuator: A device may be formed by actuators in addition to other components. By this component each one of the actuators of the device is defined. Their features are the name of the actuator, the actions that can be performed (at least one is required) and filters that might be used to identify the actuator in addition to the name.

- Sensor: A device may consist of sensors in addition to other components such as actuators. By using this component, each of the sensors available to the device is defined. Its features are the name of the sensor, which may be either in automatic or in manual operating mode (modeState), frequency of running if it is automated, and filters that can be used to identify the sensor in addition to the name.
- Rule: In addition to physical components such as sensors or actuators, a device may have rules that automate execution of the actions of its actuators, or invoke actions to actuators of other devices, being based on data from its sensors or from other sensors available in the social network. Their properties are the literal of the condition (conditionLiteral), for example "greater than", and the value that must fulfill the condition (conditionValue). In addition to these properties, a sensor has a rule (RuleSensor) and a series of executions to be performed if the condition is met (RuleExecution).
- RuleSensor: A sensor must have a rule that receives the value that will validate the condition to turn execution of actions automated. This component is an abstract component that implements two different components as there are two possibilities when selecting the rule of sensor: one or several sensors in the device itself (DeviceSensors), one or several sensors from external devices (ExternalSensors).

  1. One or several sensors in the device itself (DeviceSensors): The rules can be used to evaluate the condition. The value of one or several sensors in the same device still requires both its name and that they contain the indicated filters.
  2. One or several sensors from an external device (ExternalSensor): The rules can be used to evaluate the condition. The value of one or several sensors from an external device indicating the name of the sensor and the filters that identify the devices and/or sensors.

- Rule execution: A rule can have to perform several executions if the condition is correct or at least one execution to do. Rule execution is an abstract component that implements two different components as there are two possibilities as selecting the actuator which will make the implementation of an action: one or several actuators of the device itself (DeviceActuators), one or several actuators of external devices (ExternalActuators). This component has a number of properties shared by all the possibilities. These are the name of the action to perform and the parameters or settings that will use the action

  1. One or several actuators of the device itself (DeviceActuators): rules can perform an action of one or several actuators of the same device, yet requiring both its name (name) and that they contain the indicated filters.
  2. One or several actuators of an external device (ExternalActuators): rules can perform an action of an actuator of an external device indicating the name of the actuator and the filters that identify the devices and/or actuators (Fig. 2).

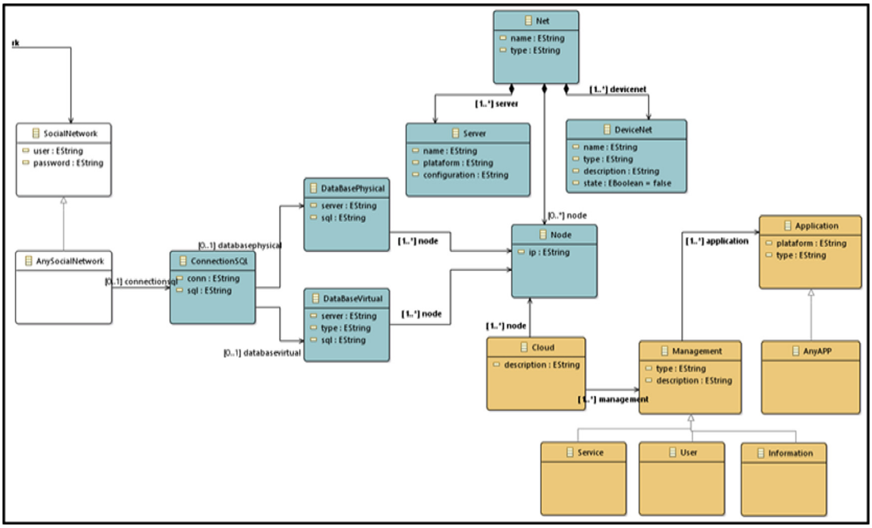

Fig. 2. Metamodel of the system. Phase II

3.1 Prototype

Within the industry 4.0 framework, the developed prototype is applicable to perform the automation of manual processes within the different productive activities in any type of industry. It implies improvements of the availability of information and its security, facilitating the flow of the information and improving the decision-making process on the implementation of corrective and preventive actions. The advantages of deployment of this class of prototypes within productive processes or for tracking products [13] relates to the decrease in uncertainty and measurement errors. In addition, the possibility of implementing a measurement process has an advantage over an interrupted manual measurement. Also, by creating processes of traceability of data and information that did not previously exist (without the intervention of the human resource) given that the gathered information is continually pushed towards the Big Data or cloud computing for its consolidation.

Based on the concepts of ubiquitous computing and communication M2M, implemented under the framework of the Internet of Things, the objective of this prototype is to capture data and provide access to them in real time and remotely. A communication environment-object and object-object was established to achieve the proposed objective. The communication environment, subject of the surveillance system, allowed to monitor several variables. For this purpose, four sensors were used. They allowed to determine the flow of products in a production plant. The presence of gas in the complex, the alignment and stability of the equipment and the existence of contact between a person and the prototype. The information on changes in the status of sensors was processed in a microcomputer Raspberry Pi.

A communication object-object between the Raspberry Pi and a mobile device was deployed with the purpose of establishing the synchronization of data directly to the user via smartphone or tablet. It was achieved through the connection established between the Raspberry Pi and the storage server in the cloud.

The prototype has the following features

- Use of technologies of sensors: the prototype uses different sensors for the detection of “strange” elements in the working environment. Then it initiates capture and data communication. The sensor acts like a link between what happens in the process and the user.
- Data collection at any time: the prototype allows capturing images and is always aware of each movement in the area where the system is deployed.
- Data Transfer: it is possible to transfer data within the communication network that is composed by the user (via a mobile device) and the physical system (Raspberry Pi) through cloud computing.
- User interface: the prototype can communicate with the user through well-known platforms or server storage.
- Functional Independence: the prototype works automatically independently of the user, since the capture of data and their transfer functions are carried out only with the activation of a sensor and a wireless network.
- Communication with the mobile device: the system does not require direct intervention to the hardware or software to operate. The communication is conducted under the principles of communication machine-to-machine, in which the microcomputer Raspberry Pi and the sensors are the prototype and the mobile device is the terminal that enables communication with the user through a server and a communication network. The collected data are transferred from one machine to another in the same way, disregarding which sensor is in use.
- Total availability of data: the system generates a communication network that allows users access in any place and request of data at any time, due to online connection of the physical prototype (Raspberry Pi) to the server (Fig. 3).

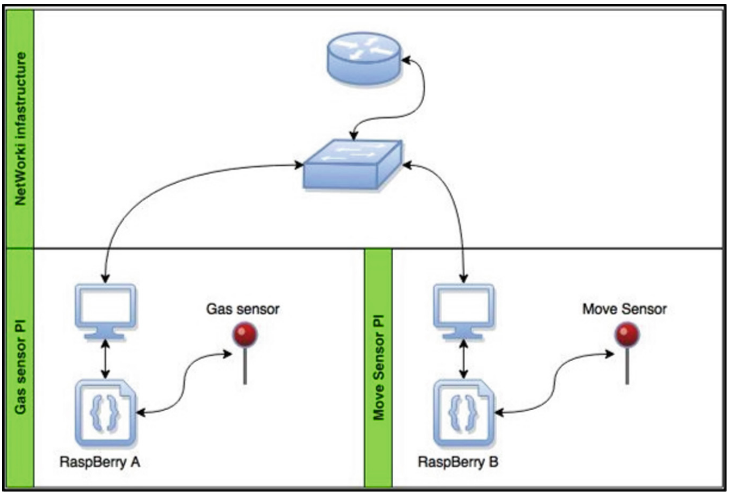

Fig. 3. Connection diagram of the prototype

4 Tests of the Prototype and Results

Tests to the monitoring system were performed with two sensors, making in each test the connection of each individual sensor to the Raspberry Pi. The tests were performed on a production line of ceramics in a period of 24 h of work (Figs. 4, 5, 6 and 7).

Fig. 4. Location humidity sensors.

Fig. 5. Location temperature sensors

Fig. 6. Location motion sensors

Fig. 7. Location of particle sensors

For the functional validation of the system devices were evaluated in parallel. In the first round, the devices already in place in the production line. It generated a failure report, stopping the process. In the second round the prototype recorded the failure and generated the report without stopping the process because it was functioning in parallel.

4.1 Stops Caused by Failures in the Production Flow

The data permitted to verify the actual condition of the stops in the production line. Some registered stops were not true failures, systems recorded them as a failure because a change in the speed of the process. The data generated by the prototype also recorded ordinary stops of and quality control stops. It forced adjustments in the decision making parameters (Fig. 8).

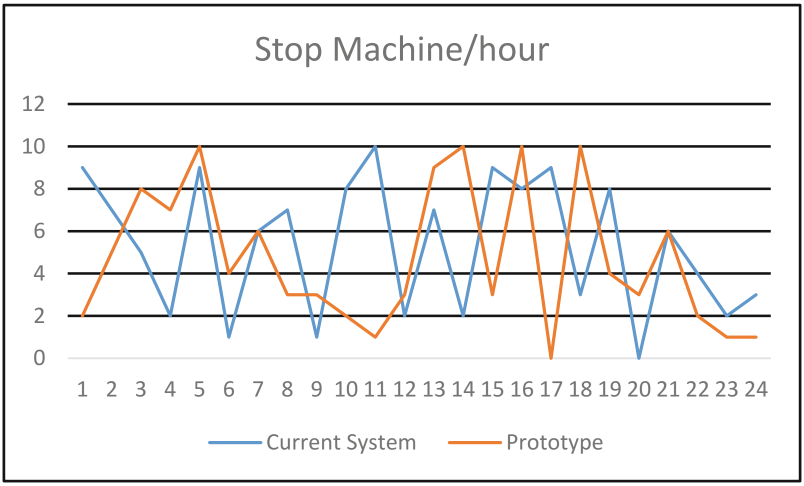

Fig. 8. Stops caused by failures in the production flow

4.2 Stops Caused by Misalignment and Instability of the Computer

The current computer does not count with this type of information, therefore it permits that the process generates failures, affecting the product. Also, it affects the equipment itself, because it subsequently generates a greater fault. The information provided by the prototype allowed to check and adjust the computer without generating any stop in the process.

The test of the monitoring system with the sensor of gas detection was carried out. Into the environment in which they were performed there was no presence of gases LP, methane or smoke. Consequently, signals sent by the sensor to the Raspberry Pi did not activate the collecting system nor synchronization (Figs. 9 and 10).

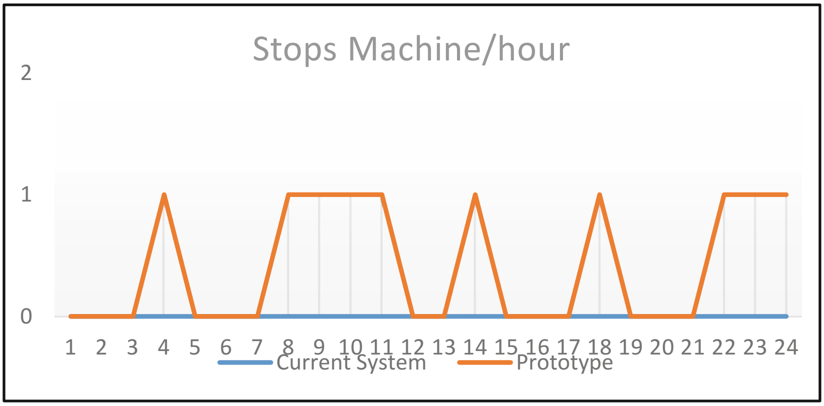

Fig. 9. Stops caused by misalignment and instability of the computer

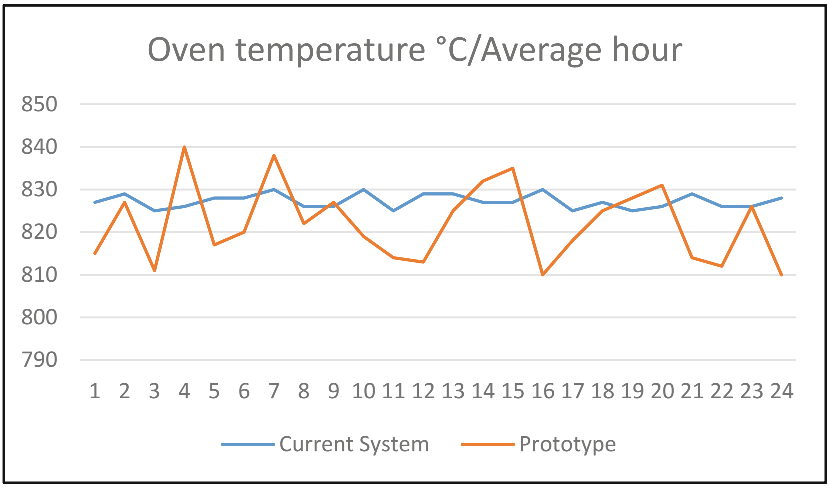

Fig. 10. Average temperature recorded

5 Conclusions and Future Work

The technology itself is not the main obstacle for the implementation of IIoT; the interfaces of interoperability of the systems belonging to different providers are, that hinders its adoption. The achievement of interoperability requires standardization of interfaces for interaction between different components of the system.

IIoT is the combination of computing technologies, communication and microelectronics. Thus, there are many interfaces between hardware, software and network components. In the context of the industry 4.0, the proposed architecture let establish communication networks between objects and people that permit the flow of information in two ways, with minimal intervention in the network. Communication networks focus on direct and comprehensive transmission of data.

The change in the way of gathering and storing the information, as much as the use of sensors, requires a change in the technology. IIOT can register automatically, precisely and timely several parameters of the production process. The traditional industrial production performs the communication between machines via the M2M technology, but the IIOT can achieve connections between people, machines and physical objects. Nevertheless, in the IIOT environment, the function and the yield of communication devices are different. Some applications need a high performance in real-time, while others do not. Some application tasks are executed periodically while others are activated by events. These characteristics increase the complexity of the actual applications of the IIOT.

Future research should focus on:

- Safety of data and system accuracy
- Standardization of technology and interoperability of systems
- Actual deployments.

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