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Additional Information

CONCEPTUAL FRAMEWORK FOR APPLYING INTERNET OF THINGS IN PRODUCTION SYSTEMS FOR SENSING ENTERPRISES

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Abstract

Sensing Enterprise is a new concept, which appears with the Internet of Things (IoT) application in industry. This technology applied in production systems provides many benefits like better transparency or real time information. This approach proposes a conceptual framework for IoT application in Production Systems. The aim of this framework is helping enterprises to identify the main elements to apply IoT in Production Systems. To create this framework, a literature re-view has been made and the main components of IoT in Sensing Enterprise in production proposals have been identify. Thus, these elements and its relations have been the source for the conceptual framework proposed.

Palavras-chave: Internet of Things; Sensing Enterprise; Production System; Information System; Conceptual Framework

1. INTRODUCTION

According to FInES (2012) the next decade is expected to see a big change in the way enterprises operate, because to the Future Internet and the huge development achieved by enterprises in adopting new technical solutions. The FInES Cluster, in its Roadmap, proposes 9 *Qualities of Being* (QB) that are considered strategic for the enterprises of the future. One of these *Qualities of Being* is Sensing Enterprise. There is a need to decentralize intelligence, moving to a scenario where the enterprise is seen as a smart complex entity capable of sensing and reacting to (business) stimuli (FInES, 2012). This concept emerges with the evolution of IoT.

Although no universal definition exists for Internet of Things, the core concept is that everyday objects can be equipped with identifying, sensing, networking and processing capabilities, which will allow them to communicate with one another, and with other devices and services, over the Internet to achieve some useful objective (Atzori *et al.*, 2010). Miorandi *et al.*, (2012) briefly summarizes the three main system-level characteristics of the Internet-of-Things as

follows: Anything communicates, anything is identified and anything interacts.

This paper focus on Sensing Enterprise and IoT applied in production systems. Thanks to the new information technologies, production processes can be optimized; the entire lifecycle of objects, from production to disposal can be monitored; and greater transparency can be gained about the status of the shop floor, the location and disposition of lots, and the status of production machines (Bandyopadhyay *et Sen*, 2011). Enterprises could take these advantages and improve their production system applying IoT.

To this end, this paper shows key concepts to implement IoT application in Production System. Section 2 shows a literature review with the application of IoT in production; section 3 includes the conceptual framework proposed to identify and organize these key concepts; and finally, section 4 includes the conclusions drawn from this research.

2. APPLICATIONS OF IOT IN LITERATURE

It is possible to find useful general proposals for a wide range of industrial sectors, but also a specific proposal for

given industrial sectors (Boza *et al.*, 2015). For example, Cao *et al.*, (2011) present a proposal based on IoT for the toy sector, and Castro *et al.*, (2011) for chemical industries, Hu *et al.*, (2011) in the meat sector, Liu *et al.* (2013) for aerospace industries and Qu *et al.*, (2012) and Wang *et al.* (2014) for the agricultural sector.

Most proposals are useful for a wide range of industrial sectors.

Cuiyun *et al.* (2010) study the influence of an IoT application on production and logistics in an enterprise.

Houyou *et al.*, (2012) design an automation system in manufacturing to support flexibility and agility in manufacturing.

Isenberg *et al.*, (2011) research about suitability and cooperation in collaborative production environments for autonomic and agile processes based on IoT.

Lvqing (2011) presents a mechanical production monitoring system based on IoT technology.

Meyer *et al.*, (2011) make an approach for a monitoring and control system to enable new ways in which disturbances can be dealt with in order to increase the robustness of overall plan execution.

Wang *et al.* (2013) design a manufacturing inventory management model based on IoT.

Yuan *et al.*, (2013) develop a system to verify that IoT promotes workshop process visualisation developments.

Zhang *et al.*, (2014) propose an Internet of Manufacturing Things like a tool to design an easy-to-deployment infrastructure to form a sensing manufacturing environment.

Zhiliang *et al.*, (2013) present a project that merges Personal Digital Assistant (PDA) in manufacturing shop with IoT.

Zuehlke (2010) designs Smart Factory KL, a multi-vendor research facility for smart production technologies.

With these applications founded in literature, the main concepts to apply IoT in production system have been extracted and joined to create the conceptual framework presented in this paper. These concepts allow knowing the main elements of IoT application for Sensing Enterprises in Production System.

3. CONCEPTS OF IOT IN PRODUCTION SYSTEM

The aim of this research is to identify and organize the key concepts to implement IoT applications in Production System

based on literature review. In order to define a conceptual framework, the key concepts of IoT in Sensing Enterprise and IoT in production proposals have been identified.

Thus, a conceptual framework for applying IoT in Production System has been proposed.

3.1. Internet of Things in Sensing Enterprise

The main characteristic of Sensing Enterprise is the promptness to react in front of disturbances due to detecting events in real time with the help of new technologies, mainly IoT. This is a new concept which allows any object communicates with others objects through Internet, and provide information in real time with new technologies, like RFID and sensors, to facilitate the exchange of goods and services in global supply chain networks (Gu *et al.*, 2014; Tan et Koo, 2014; Wang, 2014; Whitmore *et al.*, 2014).

Internet of Things is structured in three levels (Atzori *et al.*, 2010; Bandyopadhyay *et al.* Sen, 2011; Gubbi *et al.*, 2013; Gu *et al.*, 2014; Singh, Tripathi *et al.*, 2014). These levels provide all the elements to apply IoT:

Edge level: this level is formed by the physical part of IoT. ID-technologies and Sensors below to these level (Tan et Koo, 2014). This level gives to the objects the physical part to store information and give them intelligence. This part is formed by RFID (Cao *et al.*, 2011; Castro *et al.*, 2011; Hu *et al.*, 2011; Isenberg *et al.*, 2011; Liu et Xu, 2013; Shengduo et Jian, 2012; Vossiek *et al.*, 2010; Wang et Liu, 2014) and two dimensional code (Lee *et al.*, 2012; Lvqing, 2011; Meyer *et al.*, 2011; Stephan *et al.*, 2010; Zhiliang *et al.*, 2013). For reading these ID-technologies, there are sensors *et al.*, 2011; Hu *et al.*, 2011; Qu *et al.*, 2012; Vossiek *et al.*, 2010; Zhang et *et al.*, 2014) and cameras (Lee *et al.*, 2012; Shengduo et Jian, 2012). There are also Object Memory Servers (Stephan et al., 2010), to store the information in each object and database servers with enterprise information (Cao *et al.*, 2011; Cuiyun et Yuanhang, 2010; Liu et Xu, 2013; Meyer *et al.*, 2011; Wang et Liu, 2014; Zhiliang *et al.*, 2013).

Access Gateway Level: objects need a network to send and receive information between these. The management of these network belongs to these level. The possible networks are Wireless Sensor Network (Castro *et al.*, 2011; Shengduo et Jian, 2012), Mobile Communication Network (Lee *et al.*, 2012; Qu *et al.*, 2012), GPS (Liu et Xu, 2013; Meyer *et al.*, 2011), Bluetooth (Zuehlke, 2010), 6LoWPAN (Castro *et al.*, 2011) and Zigbee (Zhang *et al.*, 2014; Zuehlke, 2010).

Application Level: in this level, objects acquire intelligence through implemented software. These objects can

communication also with an application in a computer or a smartphone. This application can be new software (Cao *et al.*, 2011; Huet *et al.*, 2011; Lvqing, 2011; Wang et Chen, 2013; Wuest *et al.*, 2012) or an extended part of information system in enterprise (Houyouet *et al.*, 2012; Zhiliang *et al.*, 2013).

To sum up, Sensing Enterprises are based on Internet

of Things, and IoT is structured in three levels: Edge, the physical part (RFID, sensor, etc); Access, the part carried out of object communication; and Application, which can be new application or a module to extend the present information system (Figure 1).

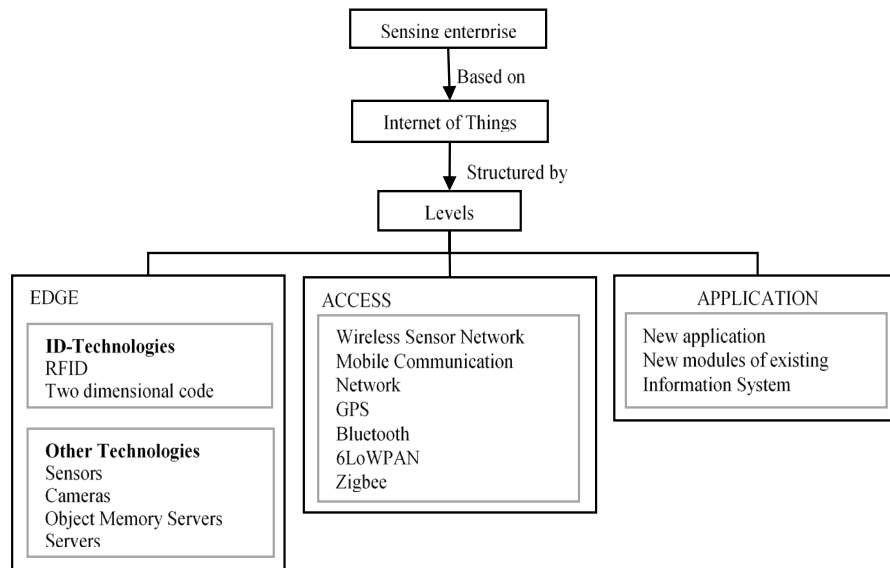


Figure 1. Main concepts of IoT Application

3.2. Internet of Things in Production Proposals

Production system is a set of tasks to manage production in an enterprise. These tasks can be classified in three phases: Planning, Operations and Control (Cuatrecasas, 1994). To manage each phase, enterprise uses different information technologies. These technologies provide information to help managers making decisions (Simchi-Levi *et al.*, 2003). IoT is one of these technologies which provides information (Cuiyun et Yuanhang, 2010).

In Production Planning, for example, inventory management application (Cuiyun et Yuanhang, 2010; Isenberg *et al.*, 2011) to know the current inventory and to plan in base of this information; or tracking management system (Cuiyun et Yuanhang, 2010; Wuest *et al.*, 2012) to know the times of transporting or production and planning with this information.

In Operation Phases, IoT application allows factory automation (Houyou *et al.*, 2012), product manufacturing workshop (Liu et Xu, 2013) or mechanical production with management system (Lvqing, 2011). The applications in this phase are also called Internet of Manufacturing Things (Zhang *et al.*, 2014; Zhiliang *et al.*, 2013).

The largest number of IoT application in production system are for the Control Phase (Liu *et al.*, 2015). In this phase, some applications are Resource Management Systems

(Lee *et al.*, 2012), to control resources to accomplish the planning; Monitoring and Control Systems for disturbances in production (Meyer *et al.*, 2011; Yuan *et al.*, 2013); tracking systems to control the necessary pieces of a product (Qu *et al.*, 2012); or a management systems to control the environment of production like agriculture or food factory (Hu *et al.*, 2011; Shengduo et Jian, 2012).

In summary, IoT provides value information, taken from production system or other systems with relevant information for production, which enriches the Enterprise Information Systems. This information systems based on IoT improves the different phases of Production System: Planning, Operations and Control (Figure 2).

3.3. Proposed Framework of Internet of Things in Production System

In this section, a conceptual framework for Internet of Things Application in Production System of Sensing Enterprises is presented. Figure 3 represents the complete framework joining the concepts presented before. Sensing Enterprise has a production system that is improved with Information Systems. Information Systems are complemented by product information provided by IoT, which is structured in three levels: Edge, Access and Application.

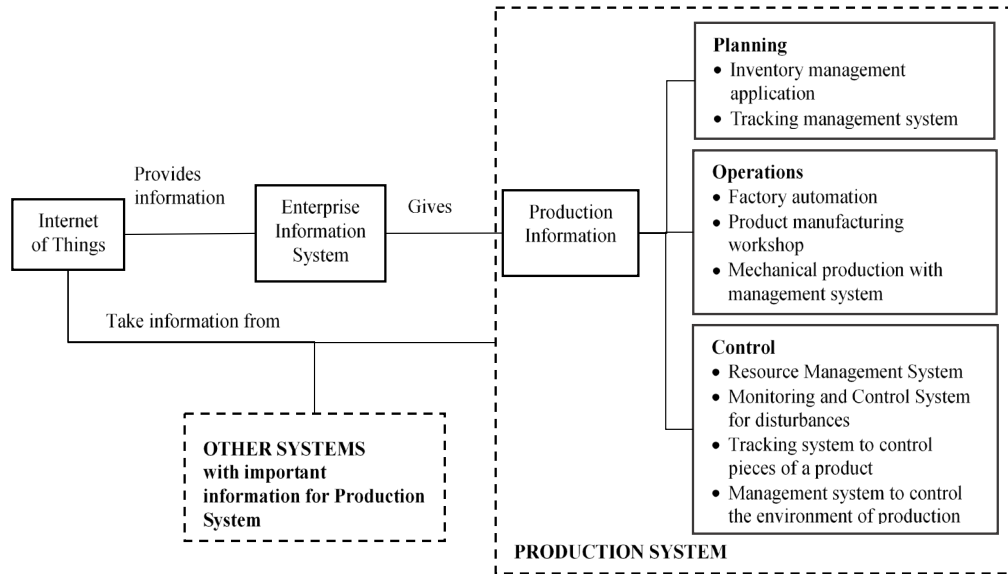


Figure 2. Main concepts of IoT in Production system

Based in these concepts, enterprise have to contemplate the phase whose information must to be improved (Inventory to plan, product localization to operate, production environment to control, etc). Then, enterprise should study the elements necessary in each level of IoT structure:

Application (What kind of application is required? Will the application be new or an ERP extension?), Access network (How are objects going to communicate? How many objects will be?) and Edge (What ID-technologies are objects going use? Are sensors going to be necessities?).

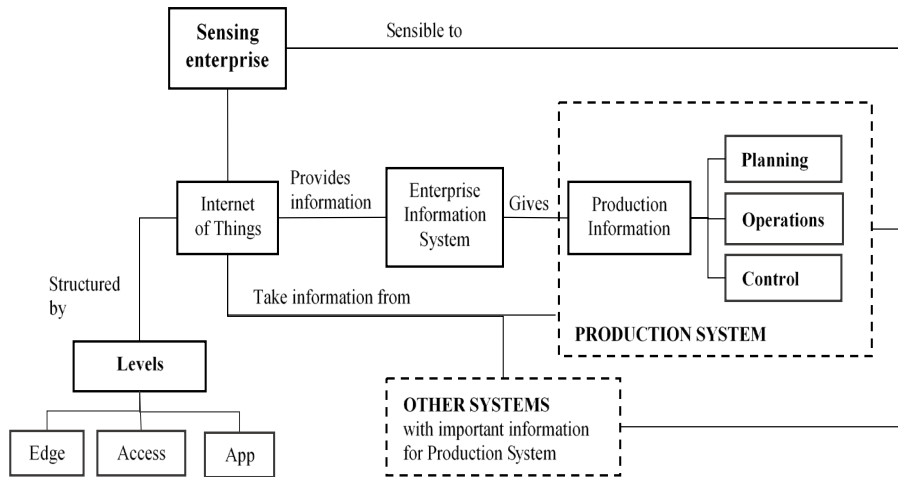


Figure 3. Conceptual Framework of IoT Application in Production System for Sensing Enterprise

4. CONCLUSIONS

This paper presents a conceptual framework about IoT in Production system inside Sensing Enterprise. To define this framework, a literature review about IoT applications in production System has been made. Even though there are few researches, main concepts of IoT applied in Production System has been extracted.

These elements help any enterprise of any sector to apply IoT and show examples of applications that improve the production system in each phase. This framework intends to help enterprises to acquire sensibility in front of disturbances in the Production System. A possible future line will be proving this framework in a real company to see if these concepts help to apply IoT.

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