Internet of Things Applications on Supply Chain Management

B. Cortés, A. Boza, D. Pérez, L. Cuenca

***Abstract*—**The Internet of Things (IoT) field has been applied in industries with different purposes. Sensing Enterprise (SE) is an attribute of an enterprise or a network that allows it to react to business stimuli originating on the Internet. These fields have come into focus recently on the enterprises, and there is some evidence of the use and implications in supply chain management, while finding it as an interesting aspect to work on. This paper presents a revision and proposals of IoT applications in supply chain management.

***Keywords*—**Internet of Things, Sensing Enterprises, Supply Chain Management, Industrial, Production Systems, Sensor.

I. Introduction

THE current global market is dominated by globalization, which creates a strong competition atmosphere. This environment of globalization and competition directs the flow of business through the supply chain (SC) or, more recently, collaborative networks (CN), since companies are not individually self-sufficient. Therefore, it is necessary that companies that mak up these chains or networks are integrated and that they coordinate their processes to become more competitive and efficient, thus enabling the fulfilment of the overall objectives of the partners and its own objectives [1].

Internet of Things (IoT) is a concept that aims to enhance the forms of communication that we have today. Currently, the Internet is a network tool that humans access using devices. The main form of communication is human-human. IoT attempts to not only have humans communicating through the Internet but also have objects or devices. These things are to be able to exchange information by themselves over the Internet, and new forms of Internet communication would be formed: human-things and things-things [2].

This paper is structured as follows. Section II describes the concept of IoT including features, architecture, technologies and applications. Section III depicts the related concept of sensing enterprise. Section IV presents the internet of things applications on supply chain management. Finally, Section V presents the main conclusions and future stepsin this research.

II. Internet of Things

A. Definitions

While there is no universal definition for the Internet of Things (IoT), the core concept is that everyday objects can be equipped with identifying, sensing, networking and processing capabilities that will allow them to communicate with one another and with other devices and services over the Internet to achieve some useful objective [3].

According to [4], IoT is the expansion of the current Internet services so as to accommodate each and every object which exists in this world or likely to exist in the coming future.

There are authors that make definitions more technological, focusing the Internet of Things like a set of technologies used to communicate the objects between them [5]–[9]. But others author define the Internet of Things like a general concept about the information exchange between objects [2]–[4], [10]–[12].

B. Features

The Internet of things is characterized by three visions, showed in [4]:

1) Things Oriented Vision: This vision is supported by the fact that we can track anything using sensors. The basic philosophy is uniquely identifying any object using specifications of Electronic Product Code (EPC). This technique is extended using sensors. It is important to appreciate the fact that future vision will depend upon sensors and its capabilities to fulfil the “things” oriented vision.
2) Internet Oriented Vision: this vision has pressed upon the need to make smart objects which are connected. The objects need to have characteristics of IP protocols as this is one of the major protocols being followed in the world of Internet.
3) Semantic Oriented Vision: This vision is powered by the fact that the amount of sensors which will be available at our disposal will be huge and the data that they will collect will be massive in nature. Thus, we will have vast amount of information, possibly redundant, which needs to be processed meaningfully.

According to [7], the Internet of Thing builds on three pillars, related to the ability of smart objects to: (i) be identifiable (anything identifies itself), (ii) to communicate (anything communicates) and (iii) to interact (anything interacts) – either among themselves, building networks of interconnected objects, or with end-users or other entities in the network.

Reference [7] briefly resumes the three main system- level characteristics of the Internet-of-Things as follows:

– Anything communicates: smart things have the ability to wirelessly communicate among themselves, and form ad

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hoc networks of interconnected objects.

- Anything is identified: smart things are identified with a digital name: relationships among things can be specified in the digital domain whenever physical interconnection cannot be established.
- Anything interacts: smart things can interact with the local environment through sensing

According to [13], the technological features of the Internet of Things are:

- Comprehensive perception, using RFID, sensor, two-dimensional code to access to the information of the object anytime, anywhere. Scope of data collection terminal connected through the Internet of Things is very broad, involving hundreds of millions of heterogeneous devices ubiquitous access
- Reliable transfer, through the wide variety of data collection terminal to achieve real-time acquisition of external environment information, the dynamic information of the object and convert it into a data format suitable for network transmission, and transfer to the data center through network.
- Intelligent processing, using cloud computing, fuzzy identify and other intelligent computing technology to analyse and process vast amounts of data and information to achieve intelligent control for objects.

C. Architecture and Technologies

According to [14], the implementation of IoT is based on an architecture consisting of several layers. The layered architecture is to be designed in a way that can meet the requirements of various industries, enterprises, societies, institutes, governments etc. The functionalities of the various layers are [14]:

- Edge layer: this is the hardware layer and consists in sensor networks, embedded systems, RFID tags and readers or other soft sensors in different forms.
- Manyof these hardware elements provide identification and information storage, information collection, information processing, communication, control and actuation.
- Access gateway layer: It takes care of message routing, publishing and subscribing and also performs cross platform communication, if required.
- Middleware layer: It acts an interface between the access gateway layer and the application layer. It is responsible for functions and also takes care of issues like data filtering, data aggregation, semantic analysis, access control, information discovery such as EPC (Electronic Product Code) information service and ONS (Object Naming Service).
- Application layer: this layer is responsible for delivery of various applications to different users in IoT.

Reference [6] identifies three more technical components of the Internet of Things: (a) Hardware: made up of sensors, actuators and embedded communication hardware; (b) Middleware: on demand storage and computing tools for data analytics and (c) Presentation: novel easy to understand visualization and interpretation tools which can be widely accessed on different platforms and which can be designed for different applications. In this section, we discuss a few enabling technologies in these categories.

About the technologies of Internet of Things, [14] presents the technology areas enabling the IoT:

Identification technology: The function of identification is to map a unique identifier or UID (globally unique or unique within a particular scope), to an entity so as to make it retrievable and identifiable without ambiguity in the vision of IoT, things have a digital identity. So, it is necessary a technology to identify the objects.

- IoT architecture technology: Scalability, modularity, extensibility and interoperability among heterogeneous things and their environments are the key design requirements for IoT.
- Communication technology: The applications of IoT form an extensive design space with many dimensions that include several issues and parameters. Such an extensive design space obviously makes IoT application development a complicated process.
- Network technology: The IoT deployment requires developments of suitable network technology for implementing the vision of IoT to reach out to objects in the physical world and to bring them into the Internet.
- Software and algorithms: One of the challenges in building IoT applications is how to design a common underlying software fabric for different environments and how to build a coherent application out of a large collection of diverse software modules.
- Hardware technology: Smart devices with enhanced inter-device communication will lead to smart systems, which have high degrees of intelligence and autonomy enabling rapid deployment of IoT applications and creation of new services.
- Data and signal processing technology: something very important in IoT is the representation of data taken by the sensor and the processing of it.
- Discovery and search engine technology: IoT will also require the development of lookup or referral services to link things to information and services and to support secure access to information and services in a way that satisfies both the privacy of individuals and the confidentiality of business information.
- Relationship network management technology: Internet of Thing will require managing of networks that contain billions of heterogeneous things, so network management technologies will have to addresses several important issues including security, performance and reliability.
- Power and energy storage technology: These technologies have to provide high power-density energy generation and harvesting solutions which, when used with today's low power nano-electronics, will enable us to design self-powered intelligent sensor- based wireless identifiable

device.

- Security and privacy technologies: Two major issues in IoT are privacy of the humans and confidentiality of the business processes. For ensuring confidentiality, a large number of standard encryption technologies exist for use. However, the main challenge is to make encryption algorithms faster and less energy-consuming.
- Standardization: Standards should be designed to support a wide range of applications and address common requirements from a wide range of industry sectors as well as the needs of the environment, society and individual citizens.

Reference [2] makes a survey of the technologies with two layers that they name the perception layer and the network layer. Comparing with the previous layer, the perception layer will be the edge technology layer and the network layer will be the access gateway layer. The perception layer is responsible for converting information into signals that can be transmitted in networks and read by applications. The commonly technologies used for data acquisition are two dimensional codes, radio frequency identification (RFID), and sensors. Two-dimensional codes are optical images that use pixels to represent data. RFID uses electromagnetic waves for data transmission. Sensors can refer to a variety of data acquisition devices. Once the information is obtained, the network layer is responsible for allowing data to travel from one host to another. For network techniques, ZigBee, Z-Wire, and 6LoWPAN are discussed. ZigBee and Z-Wire are non-standard wireless sensor network protocols. 6LoWPAN is a solution to connect wireless sensor networks into the Internet.

D.Applications of Internet of Things

The different applications of IoT have been classified in different groups.

Reference [3] represents the different applications of Internet of Thing grouped into the domains: transportation and logistics, healthcare, smart environments, personal and social and futuristic.

Reference [14] makes the groups based on the kind of Industry of each application. The groups are: Aerospace and Aviation Industry, Automotive Industry, Telecommunications Industry, Medical and healthcare Industry, Independent Living, Pharmaceutical Industry, Retail, Logistics and Supply Chain Management, Manufacturing Industry, Process Industry, Environment Industry, Transportation Industry, Agriculture and Breeding, Media, Entertainment Industry, Insurance Industry and Recycling.

Reference [6] categorizes the applications into four application domains: Personal and Home, Enterprise, Utilities, and Mobile.

Reference [4] groups in: Tracking (People, Inventory and inference regarding a specific subject), Smart Environment and Enterprise, Smart Unit, Local, Global and Social Sensing, Healthcare Monitoring Applications and Traffic Monitoring.

III. Sensing Enterprise

An important concept to know inside the IoT application in the Enterprises is the Sensing Enterprise. According to [15], 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, independently of the industrial sector, the size, the organizational model they will follow. Such QBs are considered as directions towards which to proceed, requiring specific activities to be adopted, rather than as targets to be met once and forever. The QBs are not orthogonal, instead they are interlinked and complementary; they will be briefly introduced below, in the form of enterprise predications. They are: Inventive Enterprise, Humanistic Enterprise, Cognitive Enterprise, Community-oriented Enterprise, Liquid Enterprise, Agile Enterprise, Sensing Enterprise, Global Enterprise, and Sustainable Enterprise.

Here is where the concept of Sensing Enterprise appears. It emerges with the evolution of the Internet of Things. To fully exploit the potentiality inherent of this concept, 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. At the same time, having delegated routinely activities to the lower operational levels, humans will be able to concentrate on more strategic issues [15].

To collect data from sensors, enterprises use Sensing Systems. They can be classified in two categories, in regard to the elements measured inside or outside the boundaries of the Enterprise environment [16]:

- Internal Sensing Systems provide the Enterprise system with the capability of measuring Enterprise parameters classified in two categories: Human Behavior related parameters such as presence, execution time and Performance Indicators related to core processes, management processes and infrastructure.
- External Sensing Systems monitor the environment parameters associated with exterior factors that may influence the enterprise. A set of Key Performance Indicators can be correlated with the direct impact of external factors and monitored.

According to [17], there are two recent technologies which enable the sensing enterprise become a reality:

- Real time big data analytics: A typical enterprise generates very large and diverse data sets coming from its distributed business locations. These massive amounts of detailed data can be combined and analyzed by predictive analytics, data mining or statistics. Doing this process in real-time creates a business advantage for the company by giving insight into the real-world dynamics of their business.
- Sensor networks and Near Field Communication Sensor: Networks are starting to complement the already existing

RFID (Auto ID) technologies that are already available on the market.

Reference [1] proposes an initial Framework for Inter Sensing Enterprise Architecture (FISEA), which seeks to classify, organize, store and communicate, at the conceptual level, all the elements for inter-sensing enterprise architectures and their relationships, ensuring their consistency and integrity. This FISEA provides a clear idea about the elements and views that create collaborative network (CN) and their inter-relationships, based on the support of Future Internet.

IV. Internet of Things Applications on Supply Chain Management

As we say before, there are applications of the Internet of Thins in the enterprises. We focus the case studies in companies that apply the IoT in Supply Chain as an important aspect to survive on the current competitive environment.

Reference [18] proposes a model, in the form of an ontology that describes a Supply Chain to generate a highly visible supply chain (HVSC), where the location and characteristics of all the things in the supply chain could be ascertained at any point in time. This model is for a specific Supply Chain that they call Supply Chain of Things, a combination of Supply Chain and Internet of Things. Here is where things could interact with each other and other components of the supply chain, governed by specific supply chain economic phenomena.

Reference [19] compares the Internet of Thing with the Internet for Supply Chain Management and presents a distributed architecture of SCM over the Internet of Things. They also discuss the enabling technologies of the Internet of Things.

Reference [20] exposes that the most important problem in the Pharmaceutical Supply Chain is the no- transparency with the information in the movement of the product from the manufacturers to the end-users, where is critical to enhance the operational practice of the company. This no transparency causes the counterfeiting issue. To avoid that, they propose the application of RFID and Internet of Things in supply chain information transmission.

Reference [21] analyses the effect of IOT in each link of the food supply chain. They show that the real-time, accurate information sharing which realize the intelligent recognition, location, tracking, monitoring and management for food can improve the efficiency of food supply chain and the degree of food safety.

Reference [22] exposes three specific applications of IOT in fresh agricultural products supply chain management and its benefits:

1) Fresh agricultural products quality monitoring and strict food security: The application of IOT allows to get the product information throughout the whole process involving raw materials supply, production, processing, circulation and sales. Then the consumer can use this information and decide whether to buy products.
2) Establishing management information system of fresh agricultural products and increase supply chain integration efforts: The use of the IOT in supply chain management of fresh agricultural products makes companies implement real- time monitoring for each kind of fresh agricultural products and also supervise the whole process of fresh agricultural products (including to analysis and predict the information of each link of the supply chain of fresh agricultural products). Information sharing of all supply chain process among members helps companies of all nodes connect together closely, coordinate the behaviour of members of the supply chain effectively and enhance the breadth and depth of its cooperation.
3) Reduce supply chain management cost, and improve the efficiency of supply chain management. The application of IOT can reduce the cost in any link of the supply chain.

Reference [23] presents the performance evaluation index system which based on internet of things. In the traditional performance evaluation index system of supply chain, the supply chain's factor which based on internet of thing can't be reflected. So, it's necessary to establish supply chain performance evaluation index system which based on internet of thing and then evaluate their supply chain's performance. They propose that this system should highlight performance evaluation on:

– Visualization: the supply chain based on thing of internet gives all the network items a tag, which contains all the goods' interoperability information. So the enterprise can achieve visual supply chain management. On the other hand, when reliable "items" information shares in enterprise external, it can ensure the quality of products, and help enterprise implements brand strategy.
– Network seamless change: Through the strengthen the control of information flow, capital flow and logistics flow, intelligent supply chain network help enterprises determine the material purchasing line, reduce inventory storage costs and optimize product transportation. When facing the complex environment, internet of things technology can shorten the preparation time, improve enterprise production efficiency, reduce the management cost and make the enterprise manipulate emergencies in the shortest time.
– Management process optimization: Through the directly things-things communication, management system greatly reduces the dependence on employees. In such operation mode, the whole supply chain's operation is more efficiency and it reduces the error rates of artificial. Enterprise can bring about the true sense of real-time tracking, monitoring and management.
– Information synchronization features: Once the information can share throughout the supply chain, the participants on the supply chain could synchronously keep up with customers' changing demand. When the internet of things technologies using in a supply chain, it

can trace the flow of goods. Meanwhile, it can make sure that all participants can transmit data on real-time.

Comparing with IoT Architecture, in the network layer will be the Mobile Agent technology, which is employed to deploy the logistics data processing work at the place closest to the data sources so as to reduce the amount of data transferred. In the middleware layer, will be the RFID middleware technology. It is developed for actualization of accurate operation of bottom-layer devices, real-time raw data collection, data filtering, and with the encapsulation of typical application logic. In the last layer, the application layer will be the logistics management interface which becomes simple and transparent, making the whole system congruous and reliable. Finally, to make possible this structure, the cloud computing is necessary [24].

Reference [24] analyzes the current information management for supply chain quality management. It is exposed that one of the supply chain quality management systems is the industrial traceability system. Tracing can help detect the cause of quality problems. An industrial traceability system is used to trace an entity through identifying its origin by tracing back in the supply chain, following the path of the entity through the supply chain from suppliers to consumers. It can be used to improve quality management.

Information technology enables effective supply chain quality management; due to information sharing is crucial for timely quality management and control. The several cutting edge technologies which can be integrated as part of a supply chain quality monitoring system are[24]: Service-oriented architecture, RFID, Agents, Workflow management, cross-organizational integration.

The RFID, the technology associated with Internet of Things, can help improve the effectiveness of information flow in a supply chain. Partners in the supply chain will be able to access information and practice quality control based on the data shared through RFID and other technologies. This technology enables enterprises facilitating real-time traceability. This technology combined with Internet of Things enable integrating work processes better [24].

V. CONCLUSION

This work reviews the applications of Internet of Things in supply chain management. We can say that Internet of Things is a new research field on production systems. Mainly, it is possible to find proposals for production systems in general, but also, proposals for a wide range of industrial sectors emphasizing mainly the agriculture sector. The predominant technologies are RFID and sensors. Benefits of incorporating IoT are not only for better management information in production, but also for other aspects of the production system such as improving efficiency.

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