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Supply Chain Architecture Model Based in the Industry 4.0, Validated Through a Mobile Application

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Abstract

The following research exposes different tools that bring guidelines to the supply chain to be included in the industry 4.0 and get competitive advantages, showing an architecture proposal that can be adopted by the supply chains immersed in this kind of industry. The methodology used was: first, the revision of the research literature, making an exhaustive and methodical analysis of the proposals, advances, methodologies, future investigations, results and conclusions obtained. As second, the architecture is proposed, explaining one by one the elements of it. And finally, a mobile application is created in order to validate the proposed architecture. As a result, a validation of the architecture was obtained through a mathematical model that measures the usability of it, in this way, the connection between the sensor layer and the application layer is validated.

Keywords: Big Data, Industry 4.0, Internet of things, Cloud computing, Supply chain

1 Introduction

The Industry 4.0 (I4) was born in a high technology strategy project of the German government in 2011 and it is known like the fourth industrial revolution. I4 allows a change from the "centralized" production to the "decentralized" production [1], generating a strategy to be competitive in the future [2], where the products tend to control their own fabrication process [3]. In addition, it focuses in the optimization of the value chains through the dynamic and autonomously controlled production, automating the industries through the data interchange between the links of the supply chain [4].

An integral part of the future factory is the extension and expansion of the supply chains, breaking the traditional trade barriers and transcending the four walls of just one installation, in order to work closely with the clients, the suppliers, the industrial organisms and the academic world. This idea of extended enterprise is fundamental for the whole concept of industry 4.0, where the collaborative works is seen as a way to optimize productivity [5].

In this sense, the industry 4.0 is mainly based in the Internet of things (IoT), the Big Data and the smart manufacturing [6], where the products in process, the components and the production machines collect and share data in real time [7] that can be used to predict failures [8], to improve the manufacturing [3], in the decision making process discovering weaknesses and taking in account the actual situation of the system [9]. The Industry 4.0 along with the IoT can make a great revolution in the management of the global supply chain [4] by allowing to reach unprecedented operative efficiency levels and accelerating the productivity [10], [11].

The IoT allows the device interconnection for the acquisition of data [12], including communication and collaboration between them to reach common objectives [13], [14], [15], like the resource optimization and the costs [16]. The IoT let the modern enterprises adopt new strategies based on data, and handle the global competitive pressure easily. However, the adoption of the IoT, increases the total volume data generated, transforming them in Big Data [17], for which they are needed technologies and systems designed to discover, collect and analyze efficiently different kinds of big data and extract value from them for the organization [18], [19]. Some advantages of the Big Data are that it can ignore physical and geographical constraints, it can perform the connectivity and the decentralization

of the information resources and can solve the "isolated island information" problem [18]. Narrowing the gaps between the links of the supply chain.

The cloud computing (CC) has emerged as a new paradigm to give the computation as a utility service to board different necessities of processing [20]. CC integrates technologies or architectures like the IoT and the Big Data to achieve a goal, offer a platform or build a solution [21], it is being employed more and more by the companies because it provides agility and flexibility to support the supply chain operations [22]. In the cloud computing, the users or clients see the interface of the application, due to the use of Internet like a transport unity or a link factor between applications and hardware. It is possible to access to the cloud computing at any time and place whit an available internet connection [23].
Likewise, the use of the suppliers of CC has been valuable alternatives with the objective of accelerate the learning platforms of the machines. The machine learning (ML) performs tasks that need too much execution time and require platforms able to decrease this times [24] when realizing a deep understanding of patterns [25] in the data, which help to make optimal an efficient decisions, improving the performance across the experience [26]. The main goal of the ML is the creation of a system able to give an optimal solution when information is entered into it [27].

In summary, the machine learning algorithm starts with the analysis of a "training" data set, to establish a function able to distinguish individual subjects between groups. Once this is done, the model can be applied to a new data set, and the precision of the method can be measured in this new stage [28]. The success of the machine learning in intelligence tasks is largely due to his capacity to discover a complex structure that was not specified before [29].

The data play an important role in the different decisions related with the enterprise supply chain [4], [30]. The success of any business is based in the efficiency of the supply chain that is responsible of create and maintain the links of different entities in a business, that are responsible of the acquisition of raw materials for the final delivery of the product [19].

In this way, this article presents a proposal of an architecture for the supply chain in the industry 4.0 context, which can be used by each one of the links of the chain to optimize the processes in real time, besides evaluate the architecture through a mobile application.

2 Proposed Architecture

According to the studied articles, can be noted that de industry 4.0 seeks to make manufacturing smart, that is to say it is self-conscious, self-optimized and self-configured, in order to generate economic benefits in the companies that employ it [3]. When the industry 4.0 is implemented in the supply chain, the traditional production of scattered cells gets transformed to a fully integrated production flow, automated and optimized to achieve greater efficiency and closer manufacturing relationships whit the suppliers, producers and clients [31].

In the figure 1 where identified the actors and elements that interact in the supply chain in the industry 4.0, which allowed to establish a general framework information of the links inside the proposed architecture and thus determine the different actors (enterprise, business, demand, machine learning among others), that carry out the interactions to make smart the supply chain. When a smart supply chain is generated, the information flow starts with the obtaining of date through the application of the internet of things in all the links of the supply chain, going through the cleaning and selection of date in the Big Data processes, and then sending this information to the cloud computing, where the machine learning offers the optimal solutions to then feedback the supply chain, such as demand an offer predictions, planning of distribution routes, forecast of machinery failures, optimal production planning, among others

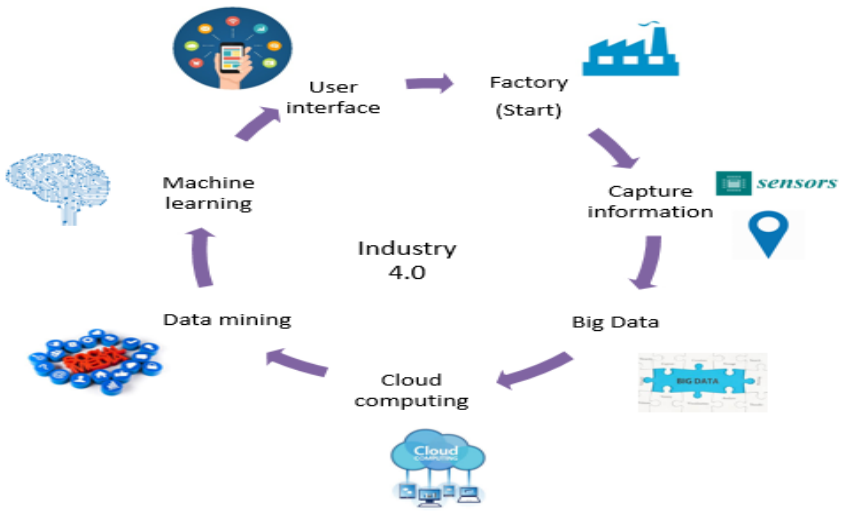

Figure 1. Interaction cycle of actors and elements in the proposed architecture. Source: Authors

The figure 2 shows a proposed architecture for the supply chain in the industry 4.0 context, in which three layers that seek for the integration of the actors and elements are defined.

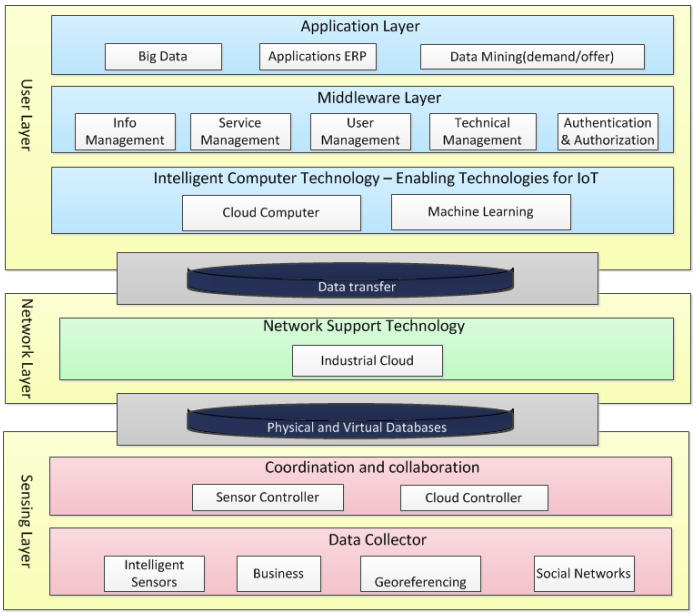

Figure 2. Architecture proposal in the industry 4.0 context. Source: adapted from [32].

Below are described the components of the architecture inside the supply chain in the industry 4.0 in order to establish an integral proposal that cover all the necessities of the organizations at the time of being part of the industry 4.0.

2.1. Sensor Layer

This layer collects the data of the supply chain through different ways, including sensors (that are in the different agents of the plant, like machines, locations and operative staff), the business component (each link of the supply chain generates information in real time, the social networks (where the communication and crossing of information between clients, suppliers and organization is generated), and for last the georeferencing elements (that take care of the location and collecting of data from the distribution channels).

2.1.1. Intelligent sensors

The intelligent sensors collect data and are complemented by actuators that take care of turn orders into actions. The following sensors were used in the links of the supply chain.

- Radio frequency identification (RFID): this technology consist in a RFID tag that contains the unique identification information of the product, a reader collects the information stored in the tag and a server system stores the data [33]. Thermocouples: were used to measure temperatures, they are usual due their low cost, wide range of temperatures and standard connections.
- Laser scroll sensor: allowed to make an exact measurement without contact with the product. The laser light changes the intensity according the dimensions of the object.
- Photoelectric barrier sensor: were used to control the specific measurements of the products.
- Load cells: was possible make a control of the weight of the products through this sensor that transmits the information to be controlled by a weight indicator.

2.1.2. Business

In the supply chain, the communication network was carried out between several enterprises, factories, suppliers and clients. Each section optimized his configuration in real time in function of the requirements and the condition of the section associated to the network, creating the maximum benefit with the exchange of limited resources for all the links of the chain [3].

2.1.3. Georeferencing

The distribution of raw material and finished products is a crucial element in the supply chain, the mission of the distribution is to get the right products to the indicated place, in the precise moments and whit the required conditions. For the distribution data collection, were used geographic information systems and global posisitioning systems.

2.1.4. Social media

The increase of the internet use promoted the use of the social networks that are connections between different actors. During the last years, the analysis techniques for social networks have acquired importance in the application and usage of data mining, providing organizations with a tool for predicting sales and market segmentation. The social networks date were extracted applying the API Rest y Streaming API techniques [34].

2.1.5. Cloud controller

It is a storage device that transfers automatically the data from the local storage to the cloud storage. In the development of the proposed architecture was used the AWS (Amazon Web Services) service.

2.1.6. Sensor controllers

The sensors controllers are devices than store and run the control programs of the sensors and actuators. For this case, ASC (Autonics Sensors Controllers) were used. This controllers are compatible with a broad range of sensors.

2.2. Physical and Virtual Databases

All the collected information must be stored, for this, data bases are used, where is safely to access the information, in the proposed architecture, two kinds of data bases were used: physical data bases and virtual data bases

2.3. Network Layer

In this layer is the infrastructure that is stored in an industrial cloud. Here is where happens the integration between the layers receiving data and supplying information to the external applications.

2.3.1. Industrial cloud

In order to access to the information of the supply chain from anywhere in real time, it is necessary to have an internet connection and access to the AWS server where the information is stored, to decentralize it and make it available to anyone who requires it.

2.4. *Data Transfer*

They were used the most common ICT (information and communications technologies) applied to the supply chain: EDI (Electronic Document Interchange) and VMI (Vendor Managed Inventory) in order to avoid information leaks and losses along the digital thread. Equally different data sources were integrated to create a holistic vision of the process from side to side. Besides, this integration of data includes information about suppliers and clients. This information is relevant for the adaptation of the manufacturing processes [35].

2.5. *User Layer*

Through an external application (app), this layer shows the monitoring of raw materials, equipment failures, quality control, production planning, demand forecast

and optimal distribution routes among others, with the aid of the cloud computing, the Big Data and the machine learning.

2.5.1. Cloud computing

AML (Amazon Machine Learning) was hired due to it allows access to the service of software and storage form anywhere through internet.

2.5.2. Machine learning

The machine learning for this architecture was supported in tools like: Hadoop, Flink and Kafka, it can be supported in other techniques developed for the organization if it requires it too.

2.5.3. Application Layer

To enter the developed application, the access is through a user account, authenticating and authorizing the access. Through the app is possible to manage the information during its life cycle (since the capture until being deleted). The application counts with a technical support module too.

2.5.4. Big Data

Through the Big Data, the data collected by the sensors layer was analyzed, selected and processed. For the development of this architecture, was used a computational system called Apache Storm, which processes constant data flows in real time.

2.5.5. Data mining (demand/offer)

The exploration of the offer of raw materials data and finished products demand data allows a comprehension of the patterns and trends of this data, in order to be processed through the Big Data. For this architecture was used Apache Storm, that uses predictive techniques like Bayesian methods and genetic algorithms.

2.5.6. ERP applications

The ERP systems were used to plan the business resources from the SAP platform. This systems typically handle the production, logistics, distribution, inventory, shipments, bills and accounting of the company in a modular way. The developed application counts with five modules: a) demand forecast, b) failure reports, c) production reports, d) suppliers reports and e) routing.

3 Proposal Revalidation

The validation of the interconnection between the sensor layer and the application layer was carried out with a test in the user phase, in which the final application was evaluated as shown in the figure 3, called ERP FOR I4, applying the "Model for the measurement of mobile applications usability, through the analysis of attributes and methods of usability evaluation" [42], that brings the guidelines in users number, experts, attributes and sub attributes.

Figure 3. User application interface based on the proposed architecture.

To re-evaluate the model, 7 experts with academic knowledge in supply chains and SAP and 8 clients involved with the organization supply chain were needed, besides to establishing the attributes, sub attributes and heuristics that are shown below: **Attributes**. a) the user understand the app functionality, b) the proposed app helps the user to interact with the links of the supply chain, c) the app works in an agile way, d) the app handles information in real time, e) the information provided by the app helps the links of the supply chain. **Sub attributes**. a) The app is easy to understand, b) the app is easy to handle, c) the obtained information is easy to analyze. **Heuristics**. a) The proposed app offers a fast way to get supply chain information, b) companies can benefit from the app and c) internet of things can benefit from the app. Once the model with the previously described properties is applied, a result of 91% of usability is obtained, like is shown in the table below

Attribute	**Validation 1**
Attribute a	95%
Attribute b	88%
Attribute c	94%
Attribute d	91%
Attribute e	87%
Usability	96%

Source: Authors

Whit the obtained data of the model in the mobile application, it is evident that the ERP FOR I4 application meets the necessary parameters to validate the proposed architecture in the interconnection of the sensor and application layers, making the supply chain integrate to the industry 4.0 successfully.

The mobile applications usability model used to evaluate the ERP FOR I4 mobile application, gave a new usability result of usability of 96%, so it can be said that the proposed architecture fulfills his function of integrate the links of the supply chain with the industry 4.0.

4 Conclusions and Future Work

As result of the presented investigation, it can be concluded that exists a positive relation between the proposed architecture and the efficiency of the supply chain, due to two main factors; the first one is related with the real time interaction between the links of the supply chain supported in the cloud computing. The second one factor is the machine learning that allows the making of optimal and efficient decisions.

The efforts made by the companies in order to create competitive advantages can be reinforced due the immersion in the industry 4.0, however, the organizations must take in account that the inclusion in the in industrial revolution brings with it changes in technologies used for the collecting, analysis and transformation of the data, and this changes mean an inversion that companies must make.

After the validation of the proposal, it was determined that the use of the developed mobile application provides an initiative to the organizations to be part of the industry 4.0, due to the interface presented is suitable for the revision of the desired information from any point of view of the supply chain in real time.

For future works it must be taken in account the security of the information through encryptions that allow the confidentiality of the data, protocols should be established for the access to the information and in addition technologies should be standardized in order to allow the integration of all the elements through different platforms.

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