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Comparative study of open IoT architectures with TOGAF for industry implementation

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Abstract

Industry 4.0 leverages Cyber Physical Production Systems (CPPS) that use IoT (Internet of Things) communication and ubiquitous computing to optimize and integrate synergistically manufacturing processes and industrial business. This increased computational and communication capability allows to dynamically interact with the physical environment providing higher performance leading the fourth industrial revolution. The benefits generated by the involvement of the TOGAF Framework in the most varied organizational models were previously discussed in the literature in a broad way, different from the application of IoT architecture, recently studied and applied in the industrial branch. Therefore, no IoT application activities based on the TOGAF structure in manufacturing processes were identified. To explore this interactivity in IoT based manufacturing systems, this paper seeks to investigate how industrial IoT application architectures are built and correlate them with the framework TOGAF (The Open Group Architecture Framework). The development of the article is defined in three steps: (i) to review the literature within the industrial context in order to consolidate the information and address different representations of the study in question to confirm the gap presented earlier; (ii) to verify the various ways to structure the information for IoT applications and correlate them with the TOGAF framework; and (iii) to elaborate a consistent critical analysis from the addressed points.

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1. Introduction

The currently globalized economic context with its intense competition, dynamism, high market complexity, the emergence of new technologies and even economic crises, offers a constant challenge for economic activities and emphasizes the importance of information to help in better decision-making [1]. Thus, a need for growth in a more and more competitive market requires companies to constantly search for new products and processes that are increasingly efficient and innovative.

As changes occur in the industries, they boost or develop activities in search of more intelligent factories, with the objective of reducing costs and decreasing delivery time [2]. With this, the technologies of industry 4.0 have been used jointly or in installments, with the result of increasing the efficiency of equipment, production and improving the availability of production assets, which has contributed and improved decision making, making them more flexible and agile factories [2,3].

The IoT, one of the pillars of industry 4.0, symbolizes the ability of smart devices to collect and analyze data in the inserted environment, which are used as a means of

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communication with the Internet or a network as a means of data sharing [4]. Connecting IoT devices results in a large number of opportunities for action, in addition to technical challenges in the industrial field, as well as the other areas [5].

Data sharing represents one of the most important characteristics of the IoT device, this step is responsible for processing and using data for the most varied purposes, so that later decision-making is in accordance with the programmed objective [4].

Information Technology (IT) has become an indispensable factor in organizations, due to its growth, and with that, it is no longer a resource that aimed to automate day-to-day tasks in the business environment. and started to play a more important role in terms of enriching the entire organizational process [6]. For this, IT must be integrated into the business processes of organizations to become a management tool with the possibility of increasing competitive advantages.

A great difficulty for managers who are going through a process of major changes is to understand the dimension of which areas, processes, and professionals will be affected and what resources will be needed. Since the knowledge of strategic value for the company's business becomes a differential for the execution of new internal approaches [7].

Corporate Architecture emerges as a methodological approach to execute and operate the company's global strategy to maintain a competitive advantage through the alignment of business and IT strategies [8]. Therefore, some frameworks assist in the approach of the corporate architecture to guarantee the correlation between the IT infrastructure and the business needs, as well as the TOGAF framework, being this, an architectural methodology to improve the efficiency of the models of business [8].

In this article, a comparative analysis of the IoT architecture with the TOGAF architecture was carried out, to align the business strategies in manufacturing companies, considering the visualization of convergent and divergent elements.

A comparison of study objects, such as TOGAF, as one of the most applied rules in the context of business administration with the Internet of Things technology since 1999, is currently the new communication paradigm with interface and interaction between objects, with the ability to connect with data via the internet. Although these two structures have different aspects, their purpose is the same, such as increased efficiency, greater control, and assertiveness for decision making.

2. Literature review

2.1. Corporate architecture

Corporate Architecture provides a strategy and an environment to align Corporate Business and Information Technology (IT). Thus, motivational factors for architecture include increasing competitiveness and facing future changes [4].

Corporate Architecture can be described as a group of documents that describe organizations from an integrated perspective of business and Information systems (IS) / Information Technology (IT), with the aim of filling the communication gap between companies and IS / IT stakeholders. For this, there are different domains and scope of the corporate architecture, as well as the high level of complexity [9]

The corporate architecture definitions can be [10]:

1. A descriptive representation (model) relevant to describe a company and what must be produced to meet the needs of management or organization;
2. A plant mapping relationship between components and all people who consistently work in the company to improve cooperation/collaboration and coordination between them;
3. A mechanism to guarantee the information technology resources of an organization that may be aligned with the organization's strategy.

2.2. Framework TOGAF

TOGAF, called The Open Group Architecture Framework, is an architectural framework that provides methods and tools to assist in the acceptance, production, use, and maintenance of enterprise architecture, based on iterative process models supported by best practices and a reusable set of architectural assets [9].

The TOGAF structure is based on four interrelated domains, these being complete descriptions that corporate architectures must contain. The four domains are: [8]

- Business: encompasses strategy, governance, organization, and key processes, as well as maximizing benefits for corporate architecture.
- Application: considers the systems, methods, and their interactions. Thus, applications are independent of specific technology options and can operate on a variety of technology platforms.
- Information System: considers the logical and physical structure of the data, that is, the data is an asset that has value for the company and is managed according to it.
- Logical Infrastructure: considers the hardware infrastructure. Also, changes to applications and technologies are made only in response to business needs.

According to The Open Group Architecture, the TOGAF (ADM) architecture development method provides a tested and cyclical process for the development of architecture. In this way, the activities of the framework are constituted by a set of steps, subdivided into steps iteratively and that indicates the activities necessary for the design, evaluation, and implementation of a corporate architecture [8]. The phases are described according to Fig. 1.

This framework describes in detail each of the expected phases, steps, inputs, and products. Therefore, at the end of each stage, the results obtained must be validated by those responsible for the corporate architecture process. The phases are explained according to [8].

- Preliminary: describes an early phase of architectural development, identify stakeholders, creates an architectural view and approves the flow of architectural development.
- Phase A: description of the development of a business architecture to support the agreed architecture vision.
- Phase B: description of the development of information systems architecture to support the agreed architecture view.

- Phase C: description of the technology architecture development to support the agreed architecture vision.
- Phase D: conducts initial implementation planning and identification of delivery vehicles for the architecture defined in the previous phases.
- Phase E: discusses how to move from baseline to target architectures by finalizing a detailed implementation plan;
- Phase F: provides architectural supervision of the implementation;
- Phase G: establishes procedures to manage changes to the new architecture;
- Phase H: The architectural change explains the procedures for managing new architectural changes.

2.3. Internet of things (IoT)

The Internet of Things (IoT), one of the pillars of Industry 4.0 based on the internet, which expands the use, and create an immense network of connections, which makes communication possible, as well as the exchange of information, to provide intelligent activity of data management, monitoring, tracking, among others [7,11].

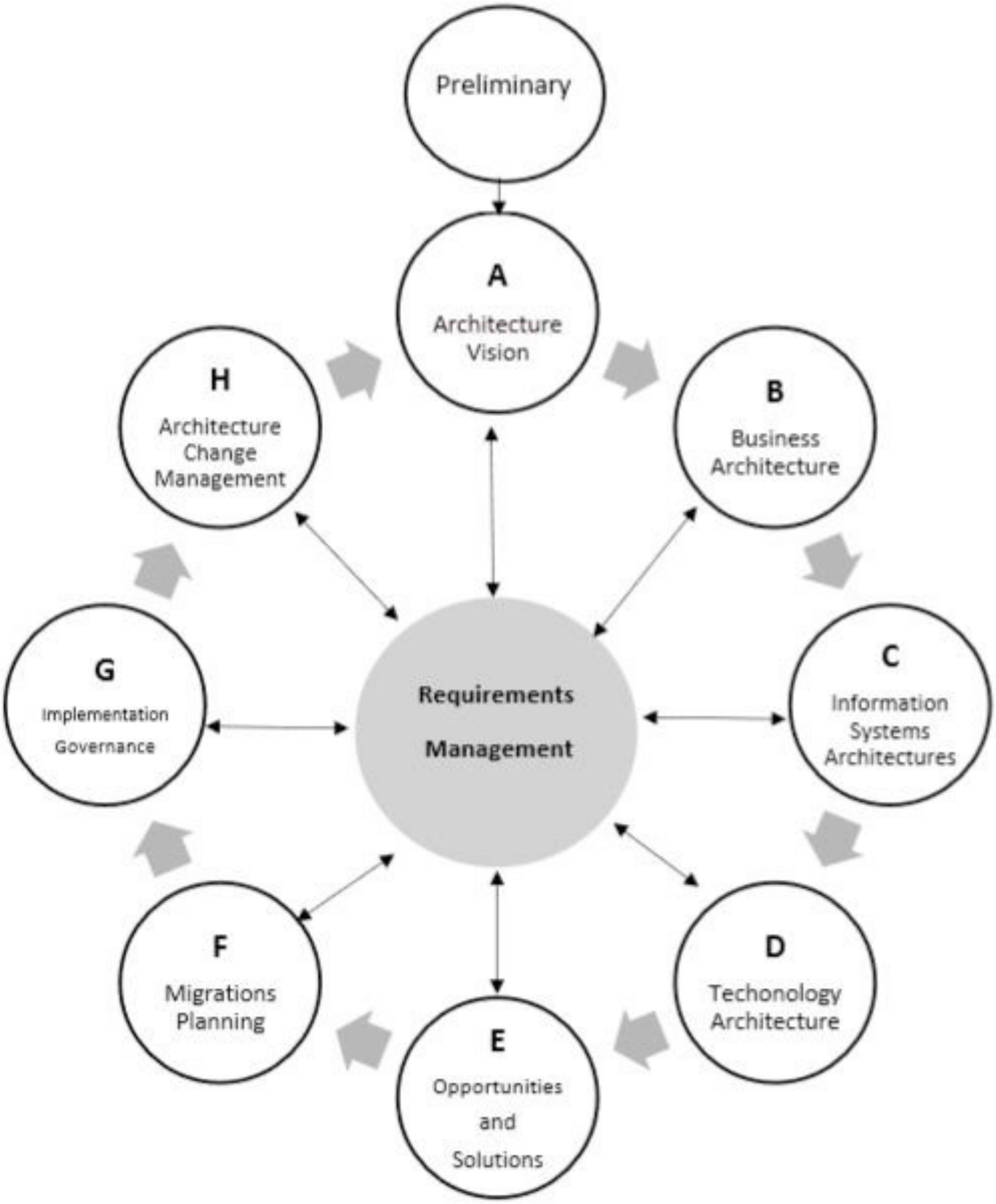

Fig. 1. Architecture TOGAF
Source: Adapted [7]

This pattern of internet connectivity between virtual and physical objects has the potential to promote interaction in different places and at any time under the desired conditions [3,12]. The need to constantly increase data accuracy and the control of machines and equipment intelligently and remotely allows for major improvements to IoT architectures [6].

The IoT architecture is generally interpreted in layers, classified into the application, network, and perception according to the way it works. The application layer highlights possible opportunities in the areas of operation, types of services and interfaces, the layer of network comprises the interactions between the software of the IoT platform and the perception layer is related to the infrastructure items and communication devices in the layer [7]. The layers are identified in Fig. 2.

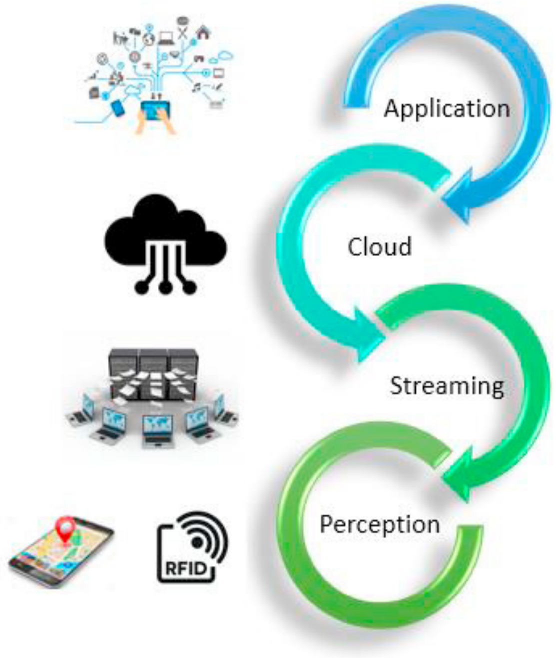

Fig. 2. The general architecture of IoT

The architecture process starts with the application layer, where data will interact with users and / or customers, through portals, applications, among others [14]. In the cloud computing layer there is a data center available, which causes data integration, that is, it stores, processes and manages data collected through the internet [7,14].

The transition layer is responsible for carrying out the transmission and acquisition of this data collected via the internet [13]. And finally, in the perception layer, information is collected and IoT communication protocol technologies are found, which according to the literature raised for this study can be: RFID, Bluetooth, Modbus, CAN Controller Network, cameras, Ethernet, Profibus, Profinet, OPC UA, Laser scanner, GPS (global position system) and options of equipment that obtain information sensors [7].

3. Research methodology

The present research consists of a bibliographic review focusing on the Internet of Things considering its architecture applied in the industrial context in the period of 2015-2020. For this review, the Proknow-C method was used as a guiding tool for the selection of the research. The search for the number of articles was carried out in 4 databases (Proquest, Science Direct, Scopus and Web of Science), with two search axes as the search words: IoT, Internet of things, TOGAF and architecture. The final number of documents consistent with the research reasoning accounts for a total of 09 articles.

Firstly, to know the characteristics is structured based on the knowledge acquired in this research, to know applications, software used, among other information about the inserted text to validate a motivating research gap.

In the second step, a critical analysis is constructed from the comparison between the construction of the IoT architecture based on those applied in the industrial context originating from the bibliographic review with the corporate architecture model conceptualized by the TOGAF framework. In addition to identifying similar and divergent points, this critical analysis also seeks to highlight opportunities for integration between the proposed models to promote improvements.

Therefore, from the analysis of articles, it was possible to carry out the research development, mainly to present a comparison between IoT and the TOGAF Framework. Fig. 3. illustrates the steps taken to follow the article.

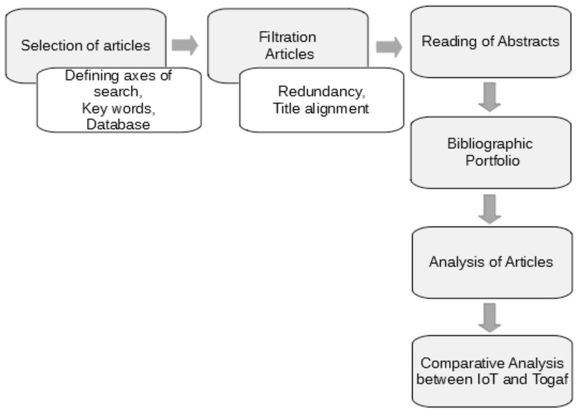

Fig. 3. Steps for the construction of comparative analysis

4. Results and Discussion

The application of IoT allows a wide opportunity for improvements and differentiated monitoring, contributing and justifying itself by the number of prototypes found in the scope of selection of recent articles.

Both architectures work in favor of horizontal integration, which is focused on working together between the areas of the same organization, thus with the growing need for data, some

IoT architectures already present proposals with the intention of vertical integration together with horizontal as is the case of the CPS 5C proposal [15]. This integration allows the process information to be shared with the organization's external agents, whether they are suppliers, customers or stakeholders, to make the data available and integrating with the chain as a whole.

The objects, hardware, software used in the development of the architecture varies greatly in type and quantity according to the need of the local situation. To illustrate the IoT application architectures found and the way they are developed, the architecture and adherence of items are directly linked to this same objective.

It is important to note that there is more than one option active in the market concerning technologies and communication protocol. They exercise their characteristics and their purpose within an inserted industrial context, and each one has its particularity about the interaction with the environment and other software on the IoT platform.

In the second step of this article, which is to correlate the two different architectures, we seek to compare a TOGAF corporate architecture with the general IoT architecture to identify similar and divergent points between them.

With the comparative analysis, it was possible to clarify the objectives of both TOGAF and IoT. TOGAF aims to provide conceptual structures from references to certify that the activities developed by software comply with the business objective. On the other hand, the IoT connects objects, people or animals for data transmission over an internet network with or without human intervention.

It was also possible to analyze their characteristics. While TOGAF aims to maintain control of the entire project, evaluating the strategic part and application of each technology item in addition to interacting with others, the IoT tends to promote connectivity between devices to facilitate data transmission, developing a standard communication between different devices, that is, a low relationship with the human element. Fig. 4 shows schematically the correlation of IoT Technology and TOGAF Framework.

Both TOGAF and IoT operate their development through layers, comparing two layers side by side as shown in Figure 4. This way it is possible to identify where the layers are related and at what point they are distinguished using arrows.

Despite both being concerned with meeting the organization's objectives, each one takes into account different points. While the IoT focuses on the collection, sharing, and propagation of data on the internet to enable faster information and more assertive decision-making to seek to solve the problem, the TOGAF architecture is concerned to describe a model to achieve the business objective already worked on, and which parameters should work according to that model, as each oscillation can be decisive in the final part of the result.

Another curious point is that TOGAF measures its activities and actions through the content initially pointed out in the Business Architecture, so all activities and objects are fully acting according to the initial planning of the corporate business architecture, whereas the IoT platform first identifies what the customer wants, and then lists which items will be used to meet the demand, the focus is on the final product, that is, on the application.

Thus, this article analyzed the layers of IoT Architecture with the TOGAF Framework, which are justified, in detail, below:

IoT Application - TOGAF Application: for this correlation, possible opportunities were considered in the areas of operation, types of services and IoT interfaces, network layer, which comprises the interactions between the IoT platform software, as well as the TOGAF Framework application, considering the architecture of applications, systems, methods, and their interactions.

Cloud - Information System - Logical Infrastructure: considers an available data center that integrates the data, that is, stores, processes and manages the data collected via the internet, as well as the Information and Infrastructure Systems, with the technological architecture to organize the infrastructure of hardware.

Transition - Information System: in this analysis it is presented as responsible for the transmission and acquisition of

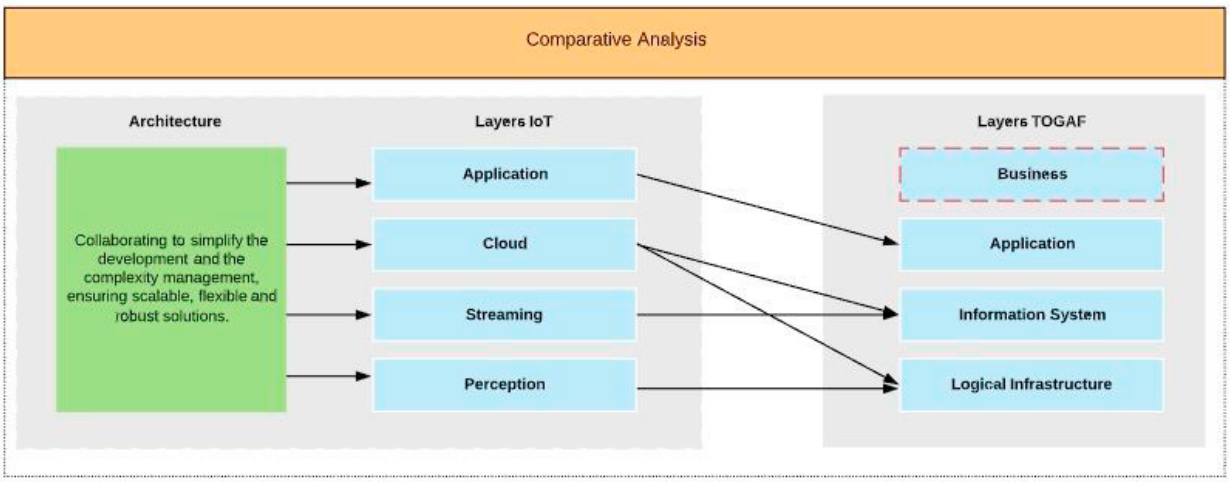

Fig. 4. Correlation of IoT and TOGAF layers

data collected via the internet, considering the logical and physical structure of the data (data architecture).

Perception - Logical Infrastructure: presents the infrastructure items and communication devices acting in the physical part, that is, the hardware, as well as in the Logical Infrastructure.

Business: the Business layer has no correlations within the specific perspectives of the pointed layers.

Considering the form of development of the TOGAF architectures with the general standard of the IoT architectures, it is possible to emphasize that the IoT can be developed within the TOGAF structure mainly in the application phase of the technologies since it represents the implementation stages of technology. However, the complexity of the TOGAF architectures and the different line of action of its layers differs from the process that, before, was very objective and in the TOGAF context it guides, creates an order, but does not highlight important points of development.

5. Conclusion

This study was moved from the literature review on IoT Technologies and the TOGAF Framework, to develop a comparative analysis, where its layers and characteristics are highlighted. For this analysis, the study showed a correlation of the IoT layers with the TOGAF layers, mainly in the Architecture Technology phase.

For the analysis, it was evaluated that both themes (IoT Technologies and Framework TOGAF) have as a common point the development of solutions through layers. As a result, it was possible to identify where the layers are related and distinguished.

Among the analysis carried out it was also possible to notice that both are interested in meeting the organizations' objectives. Also, it was possible to identify opportunities for new adaptations and improvements in the technological context according to each need and a large number of prototypes developed at the beginning of architectures to improve the dynamism of the technology to which it is applied.

The IoT and TOGAF are non-conflicting, meaning that the implementation of IoT solutions could benefit from the structural rigor of the TOGAF standard, as they would allow the development of solutions that look at the company as a whole and align with business objectives, in addition to allowing data exchange and interoperability with other systems.

The main contribution to the research between the correlation between IoT and TOGAF is the integration and alignment of business strategies in the scope of manufacturing.

According to the research, suggestions for future work are the development and application of models based on the correlation between IoT Architecture and TOGAF Framework in manufacturing companies. Then, apply this model to validate the initial notes of this research.

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