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Original Article

Internet of Things Platform (IoT) - Comparison of Layered Architectures

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Abstract - *Internet of Things (IoT) is considered the third wave of the information industry, and the main objective is the connection of four important pillars: objects, data, people, and processes. To achieve this goal, it is necessary to have an adequate architecture for the implementation of IoT in an efficient manner. However, being an emerging area, the research and architectures for proposed IoT are diverse. They are oriented to different environments such as agriculture, education, and health with different perspectives. In this study, a comparison of some architectures used in different works was made. Based on this comparison, an architecture for IoT platforms is chosen to facilitate implementation.*

Keywords - *Architecture, Cloud Computing, Standards.*

I. INTRODUCTION

Within the technological advance of recent times has emerged a new emerging trend called the Internet of Things (IoT) [1], which is defined as the digital interconnection of everyday objects with the Internet; observing it from a perspective deeper, the IoT is the communication between people and objects through specific processes that generate data, all this through the Internet [2].

The main function of IoT is to allow communication at any time, anywhere, and with any object [3]; this includes then, giving the ability to all objects to act without the need for human intervention and not only electronic devices, integrating sensors and microprocessors to its architecture to send and process information through the internet.

This goal is not very distant, and Cisco estimates that by the year 2020, there will be 50 billion connected devices, 7 times the world population [4]. Other sources, such as the Connected Life initiative sponsored by the GSMA (GSM Association), estimate that by 2020 there will be 24 billion devices connected to the Internet. And it is also estimated that 5% of objects built by humans currently have integrated microprocessors [5].

Another important aspect to take into account is that IoT is not a unique technology but rather a heterogeneous mixture of different hardware and software technologies [6]; as a consequence, the adaptation of classic industries and technology is required to provide opportunities for the emergence of new industries and to offer new experiences and services for users [5].

They [7] also mention some difficulties that the IoT must face. For example, an immense measure of information to be handled progressively by the IoT gadgets sent in the shrewd systems; and the remarkable fracture obtained from the different IoT models and the related middleware.

Various investigations have been devoted to finding and proposing suitable architectures for the construction of IoT platforms. The most common are layered architectures consisting of 3 to 7 layers. However, given the heterogeneity of the fields of application, a different architecture is occupied according to the purpose for which it was built, for example, in health, education, agriculture, or smart cities, to mention a few.

The present investigation compares the architectures proposed by some works developed from two perspectives. First, the number of characteristics and requirements that are fulfilled according to the International Telecommunications Union (ITU), and second, the number of layers it has. This document is ordered as follows: in section 2, works related to the research topic are mentioned, section 3 describes the characteristics that IoT architectures must fulfill, section 4 the methodology that was followed to perform the comparison, and section 5 describes the results of the comparison and section 6 a conclusion of the topic.

II. RELATED WORKS

J. Guerrero Ibáñez et al. [8] present SGreenH-IoT, a low-cost IoT platform with energy consumption to monitor fields and greenhouses. The platform has a 4-layer architecture shown in Figure 1, which are: a) Collection representing the hardware of the platform, consisting of the sensor nodes to measure environmental variables such as humidity, air temperature, and soil. b) Communication for data collection and storage transmission uses the ZigBee radio. c) Management is responsible for guiding all actions to analyze data implemented by the central server, and c) Query, this layer, is responsible for the end-user's interaction with the platform.

The results obtained through experimentation show the effective functioning of the platform for data collection and integration with decision making, with a percentage of data loss of zero percent.

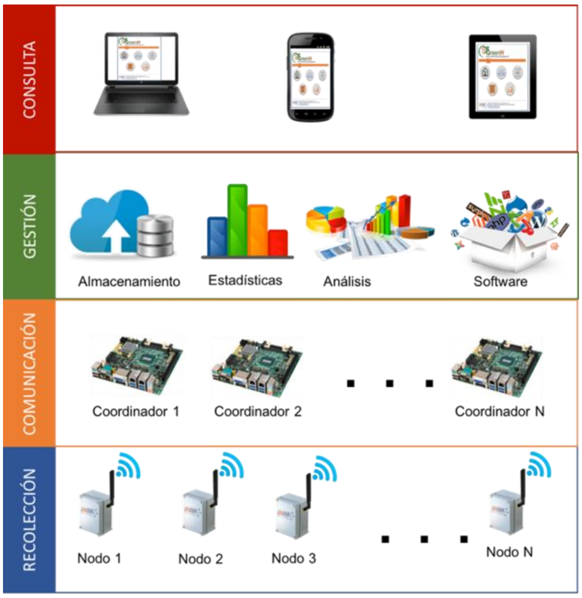

Fig. 1 Architecture of the SGreenH-IoT platform
Source: J. Guerrero Ibañez et al. [8]

Prasant Sharma and Alka Agrawal [9] mention a simple, flexible, portable, interoperable, and scalable architecture. In this architecture, four layers are used: Application, Gateway, Server, and Objects. This architecture is characterized because N numbers of objects are connected to a single server; this depends entirely on the server's hardware configuration since the server must receive *n* requests and answer them efficiently.

With the Gateway API of this architecture, the server can use other servers belonging to the IoT infrastructure and vice versa. This is the main benefit of this architecture. At the same time, it is recommended to manufacture (objects) IoT devices so that they only connect to one server at a time, not to two different servers at the same time. This is to avoid creating ambiguities.

Keyur K Patel1 et al. [6] also propose an IoT architecture consisting of four layers of technologies that support IoT. In the same way, these layers are called the Sensor layer, the Gateway layer, and the networks. The third layer is the Management service layer, and finally, the Application layer.

Dina Gamal Darwish [5] proposes an improved layered architecture for seven-layer IoT shown in Figure 2, takes all the functions of the traditional architecture, and distributes them in the seven layers but more reliably. The layers are as follows: 1) Application, 2) Application support and a management layer, 3) Service layer, 4) Communication layer, 5) Network layer, 6) Hardware layer, and 7) Environment layer.

Dina [5] separates the Management layer and adds the Services layer; in the Management layer, they perform all the actions related to the application's control, security, and administration. On the other hand, they take all the decisions related to the supervision, storage, organization, and visualization of the information received in the service.

In the same way, it separates the Communication layer and adds the layer of Networks; in the Communication layer, decisions are made related to communications, flow measurements, its quality, and consumed energy, in the Network layer has the function of Gateway, Routing and addressing, Network capabilities, Transport capabilities, Error detection, and correction.

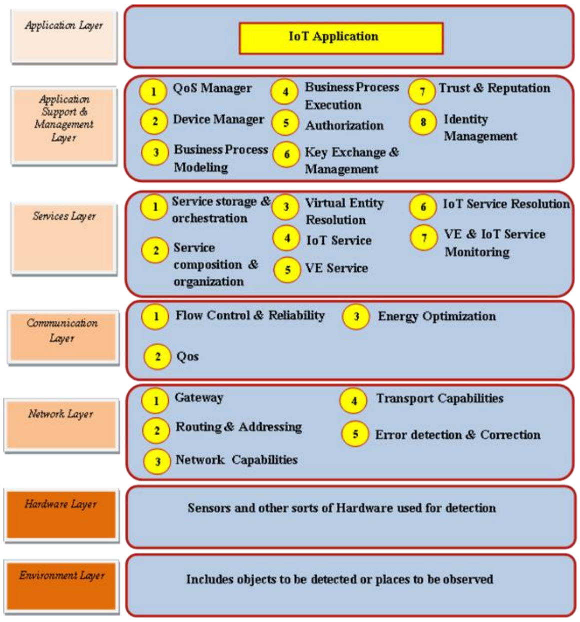

Fig. 2 Seven-layer architecture
Source: Dina Gamal [5]

Another important feature of this architecture [5] is that it adds a layer called Environment that includes objects to be tracked or places to be observed since, in a real environment, there are objects in constant movement.

Gubbi et al. [10] argue that most of the proposed architectures are from the perspective of wireless sensor networks, so an architecture based on cloud computing is proposed. However, this may not be the best option for each application domain, particularly for defense, where human intelligence is trusted. This architecture comprises three layers, a) Hardware: composed of sensors, actuators, and integrated communication hardware, b) Middleware: storage and on-demand computing tools for data analysis and c) Presentation: visualization, and interpretation tools. Several implementations [11-12] have opted for this architecture based on cloud computing, such as education and precision agriculture.

Cisco [2] proposes a similar architecture consisting of three functional layers that are: a) Application layer that provides application-centric responses to changing traffic and usage demands, b) Platform layer, which provides organization, administration, and policy adjustments according to changes in demand to accelerate service provision and c) Infrastructure layer that integrates security, central networks, access and storage architectures with physical and virtual resources.

Finally, Shi Yan-Rong and Hou Tao [13] exhibit an architecture proposed by the ITU in 2007 composed of five layers: a) Perception layer to obtain the various types of static/dynamic real-world information through various types of sensors, b) Access layer to send information from the perception layer to the Internet through the many communication networks, c) Internet layer to establish an efficient and reliable infrastructure platform for top management and large scale, d) Service administration layer to manage and control in real-time large amounts of information and e) Application layer to integrate the function of the underlying system and create a practical application for all types of industries.

However, in 2012 this architecture changed through the Y.2060 recommendation, where a four-layer architecture similar to those suggested in [8-9] and [9] proposes as an improvement. This architecture consists of four layers: a) Application layer, b) Support layer for services and applications, d) Network layer, and e) Device layer. In addition, security and management capabilities were considered that must be present in all layers, as shown in Figure 3.

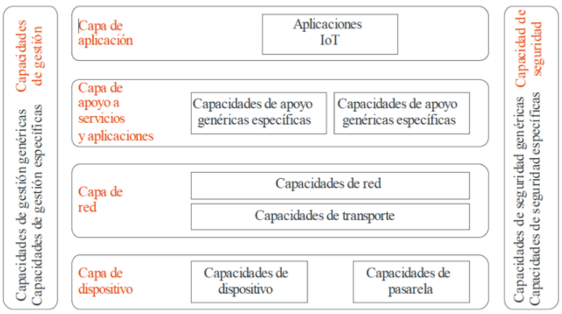

Fig. 3 Proposal architecture by the ITU

Source: Recommendation Y.2060 [3]

III. ARCHITECTURESIOT

The IoT architectures proposed in many research pieces have peculiar characteristics that will be highlighted later. However, based on recommendation Y.2060 [3], there are fundamental characteristics and high-level requirements that every IoT platform must meet, which will be achieved by choosing the appropriate architecture. Below are the characteristics and aspects necessary in detail.

A. Fundamental characteristics of IoT

- **Interconnectivity:** With IoT, everything can be connected.
- **Object-related services:** IoT can provide services related to objects within the constraints of objects, such as privacy protection and semantic coherence between physical objects and their corresponding virtual objects.
- **Heterogeneity:** Devices in IoT are heterogeneous since they are based on different hardware platforms and networks.
- **Dynamic changes:** The state of the devices varies dynamically, for example, from idle mode to active, connected and/or disconnected, location and speed.
- **Huge scale:** The number of devices to be managed and communicating with each other can be greater than the number of devices currently connected to the Internet.

B. High-level IoT requirements

- **Identification-based connectivity:** The IoT needs to establish connectivity between an object and IoT with an object's identifier.
- **Compatibility:** It is essential to ensure compatibility between heterogeneous and distributed systems to supply and consume various types of information and services.
- **Automatic networks:** Network control functions must have self-management, self-configuration, self-establishment, self-optimization, and self-protection capabilities.
- **Automatic configuration of services:** It is necessary to configure the services from the data of the objects acquired, communicated, and processed automatically according to the rules configured by the operators or customized by the clients.
- **Location-based capabilities:** It is necessary to detect and track information about the location automatically.
- **Security:** Security must be provided in confidentiality, authenticity, and integrity of data and services.
- **Services related to the human body of high quality and safety:** IoT must support these services. Each country applies different laws and regulations to these services. The services related to the human body refer to those provided through the acquisition, communication, and processing of data related to the static characteristics of the human body and the dynamic behavior with or without human intervention.
- **Autoconfiguration:** IoT must support autoconfiguration for gradual integration, the cooperation of objects interconnected with applications, and meeting applications' needs.
- **Management capacity:** IoT must support the administration capacity to guarantee the normal functioning of the network.

IV. METHODOLOGY

To compare the architectures mentioned above, five important aspects were taken, as shown in Fig. 4; first, the number of layers; this aspect is relevant given that each layer is a mixture of heterogeneous tools that must work efficiently. The second aspect will be the distribution of the tools and services used in the platforms. Subsequently, its fundamental characteristics will be compared. Finally, standards or companies that support these architectures for their implementation will be listed.

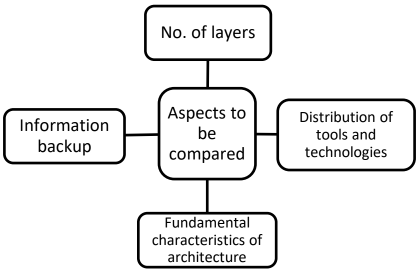

Fig. 4 Aspects to be compared of the proposed architectures
Source: self-made

V. COMPARATIVE RESULTS

Based on the comparison of Table 1 of these four architectures, the four-layer architecture will be chosen as the most optimal to implement an IoT platform, firstly because of the structure it has, since it is about dividing the collection area and control with communication and transport of data and the aspect of information management, as a result, allows fast and efficient development of IoT projects to delimit the task of each person who is used in the second place to choose this architecture is the backing of the ITU (International Telecommunication Union) with the recommendation Y.2060 where a similar architecture is described and as third place is the support of the different works that implement the IoT platforms as [8-9] have chosen this architecture to have the guarantee of the experience.

The purpose of this investigation arose from the need to build an IoT platform for the remote management of AC Receptacle. Its main feature is to have a WEB platform where the physical location of the AC Receptacle is shown graphically and sends the instruction to allow or deny the passage of energy in any of them that is synchronized with the platform, the communication between the WEB server and the AC Receptacle is through WiFi, one of the goals was to guarantee the delivery of the instructions to the recipient. To be sure that the order sent from the application layer was executed correctly in the control layer, for this reason, the choice was the four-layer architecture shown in Fig. 5. However, some features have been adapted to ensure a result satisfactorily.

Table 1. Layered Architecture Comparison

Source: self-made

No. Article	No. Layers	Distribution of tools and services by layer	Fundamental characteristics	Standards that support them
1	3 layers	Layer 1: • Microcontrollers • Sensors and actuators • Wireless communication modules • RFID tags Layer 2: • Servers • Network devices • Communication protocols • Applications for the analysis and storage of information Layer 3: • WEB and mobile applications. • Business applications and profit models • Applications for user privacy	• Architecture centered on the user. • Based on cloud computing. • Suitable for cost-based services.	The architecture proposed by Cisco
2	4 layers	Layer 1: • Microcontrollers, sensors, and actuators • Wireless communication modules • Integrated systems • RFID tags Layer 2: • Servers and network devices • Communication protocols Layer 3: • Tools for the storage, analysis, and visualization of information • Tools for data security	• Architecture focused on communication. • Separate the management of information with tools for the communication of tools. • This architecture is the most used.	The architecture supported by ITU Recommendation Y.2060

		• Virtual entities Layer 4: • Mobile and WEB applications • Business applications and profit models • Applications for the privacy of users		
3	5 layers	Layer 1: • Sensors and actuators • Integrated systems • RFID tags Layer 2: • Devices capable of connecting and sending information over a 3G / 4G network, WiFi, Bluetooth Layer 3: • Network devices • Communication protocols Layer 4: • Tools for storage, analysis, and visualization of information • Tools for data security • Virtual entities Layer 5: • Mobile and WEB applications. • Business applications and profit models • Applications for user privacy	• Architecture focuses on intelligent decision-making. • Architecture for the treatment of large amounts of information by focusing on adequate network infrastructure.	It was not found.
4	7 layers	Layer 1: • Devices for observation and detection. Layer 2: • Sensors and actuators • Integrated systems • RFID tags Layer 3: • Network devices • Communication protocols Layer 4: • Tools for energy optimization. • Tools and standards to improve the quality of processes. Layer 5: • Storage and organization services and tools • IoT and VE service • Tools for the visualization of the information Layer 6: • Services for the modeling of business processes and their execution • Tools and services for access control, authentication, and key exchange Layer 7: • Mobile and WEB applications • Business applications and profit models • Applications for the privacy of users	• Architecture that prioritizes the quality of obtaining and processing information. • Consider the existence of objects in constant motion that need to be tracked and observed. • It focuses on the reliability and safety of processes.	It was not found.

Fig. 5 Layers of the chosen IoT architecture
Source: self-made

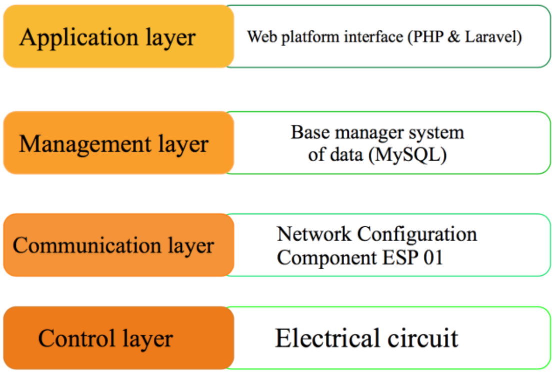

Fig. 6 Diagram of the use of each layer in the implementation with the IoT platform.
Source: self-made

The layers were called the Control, Communication, Management, and Application layers. To demonstrate the operation of the proposed architecture, an IoT platform was designed; in Fig. 6, a diagram is shown where the use of each layer is exemplified in the way it is implemented in the IoT platform. In the control layer, an electronic circuit is used as an actuator to allow or deny the passage of electrical energy in the AC Receptacle. The TCP / IP protocol is used for the routing and WiFi communication between the ESP01 devices and the WEB server

in the communication layer.

MySQL is used as a database management system characterized by two main functions in the management layer. The first corresponds to the storage of the operations generated by the ESP01 module; this information is used to generate the activity history of the platform, which is used in the WEB interface to show the monthly use of each AC Receptacle graphically; the second function is to store the data of the users and the ESP 01 modules that will interact with the platform.

In the Application layer, we have a WEB interface that was developed with the LARAVEL 5.2 framework, and the WEB interface shows in a visual and centralized way all the devices to be controlled (AC Receptacle), in addition to showing the activity or time of use of the AC Receptacle every month.

This architecture has been focused on the client. For the implementation of the WEB platform found in the Application layer, an agile development methodology has been followed by prioritizing the final user's needs.

It is necessary to consider that the proposals described in the article are logical architectures and gives the freedom to choose the type of hardware and software tools that make up the IoT platform because it is a heterogeneous but functional mixture of these tools which makes IoT.

VI. CONCLUSION

The four-layer architecture was chosen based on the comparison as it is the most suitable for a fast and secure implementation. However, for a successful choice in the first place, it is necessary to define under what perspective the IoT platform will be built; as discussed above, it can be focused on safeguarding the data collected, in the transport of these or the end-user, so it is therefore necessary to carry out an analysis of the approach that the implementation will take.

It should be noted that IoT has different types of architectures. Layers analyzed the architectures, but other proposals were based on cloud computing, fog, or the traditional client-server model. However, there are few standards or references on which to base the implementation of the IoT platform, which shows that it is an emerging technology. As an advantage, it gives the possibility of creating and proposing new architectures to improve the IoT implementation in the real world.

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