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A CASE-STUDY VISION

Functional analysis for PIICO IoT platform

Análisis funcional para la Plataforma IoT PIICO

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Abstract

This paper presents the main challenges of an Internet of Things (IoT) platform. In this sense, an interoperability platform for IoT devices, called PIICO, is presented in the frame of an agriculture application. PIICO is a platform able to resolve interoperability between components and has the potential to be a stable IoT platform. Improvements opportunities of the main IoT PIICO components (nodes, gateway, and data analytics platform) are presented and discussed.

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The proposed improvements will make that an IoT platform improves its functionality, operation, security, and performance.

Keywords: IoT Node, IoT Gateway, Data Analytics platform, Big Data, Internet of Things, agriculture.

Resumen

Este documento presenta los principales desafíos de una plataforma de Internet de las cosas (IoT). En este sentido, se presenta una plataforma de interoperabilidad para dispositivos IoT, denominada PIICO, en el marco de una aplicación agrícola. PIICO es una plataforma capaz de resolver la interoperabilidad entre componentes y tiene el potencial de ser una plataforma de IoT estable. Se presentan y discuten las oportunidades de mejora de los principales componentes de IoT PIICO (nodos, puerta de enlace y plataforma de análisis de datos). Las mejoras propuestas harán que una plataforma IoT mejore su funcionalidad, operación, seguridad y rendimiento.

Palabras clave: Nodo IoT, puerta de enlace IoT, plataforma de análisis de datos, Big Data, Internet de las cosas, agricultura.

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1. Introduction

Internet of things (IoT) has become a widely used concept for solving needs through applications in various sectors of the economy worldwide; according to Globe News Wire website, it is a $14.5 trillion business by 2020 [1]. This technology every year takes on more strength, driven by the various advances of electronics, communications networks, and data analytics fostered by cloud storage services. [2].

Internet of Things, in general, is a network of devices integrated by several technologies and communication protocols. It consists of a network of sensors and actuators, Gateway equipment, and a system for storing and managing data collected [3]. IoT systems are deployed in everyday objects such as domestic appliances, vehicles, production lines, among others; communication protocols can be wired or wireless, the latter being the most widely used, namely: Zigbee, LoRa, Bluetooth, and WiFi, among others. IoT device data is routed to the internet by a Gateway device [4]; information is then stored and processed in the cloud to provide services based on data collected from IoT devices [5].

One of the challenges of IoT is the great variety of technologies, mutually incompatible communication protocols, diversity of manufacturers, and the maturity level regarding the standards IoT devices must meet [6]. All this hinders the interoperability these devices must have with other components of an IoT system, e.g., information processing platforms. [7]

One contribution to the solution of the interoperability problem was the incursion of Samsung into the IoT market with the Artik project back in 2015; it offered a multi-protocol Gateway and complimentary services for IoT applications development [8]. Despite the expectation generated, market evolution forced the company to close the project and the approach to its IoT product and service line. Samsung is currently working with the Open Connectivity Foundation (OCF) to establish common standards for IoT interoperability among various manufacturers, along with companies such as AllSeen, Alliance, and OpenIoT [9].

Regarding the areas of IoT application, there are systems and devices for home automation, smart cities, agriculture, logistics, health, and wellness [10], smart grids [11], among others. For the Colombian case framed within its Sustainable Development Goals (SDG) that were established to be met with the 2030 agenda [12], projects are being proposed and aimed at smart cities, sustainable communities, zero hunger, and actions to combat climate change. In this context, from an IoT perspective [13], most efforts focused on smart agriculture activities have made progress in approaching benchmarks for intelligent and precision agriculture [14] as well as with device connectivity [15], power autonomy challenges, [16], data collection,

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storage [17], data processing, and finally exploitation or publication of information [18] and/or services. [19].

Considering all the above, the University of San Buenaventura, headquartered in Bogotá, through the research group SOLSYTEC has been working on a project entitled "Platform for the Interoperability of Internet of Things devices (PIICO)", a platform which consists of three main elements: Nodes, Gateway, and an analytics cloud-based component. The system has been evaluated in the measurement and transmission of environmental variables from sensor nodes, using three different WLAN protocols, to a multiprotocol Gateway which sends the information to the cloud. Subsequently, in a data analytics component, the processing of the measured environmental information is being performed [20]. The Gateway essentially functions like a bridge between the nodes, as a source of sampled data, and the cloud-based component that performs data analytics and processing.

Project PIICO is a development that complies with the functionalities of an IoT system and it is a partial solution that allows interoperability with devices that use different communication protocols. However, it is necessary to improve upon some elements that constitute the PIICO platform to strengthen its long-term operation and stability; hardware and software modifications need to be considered due to updates in some system components, and all changes proposed must be integrated into the cloud component. This article examines the components of PIICO and outlines opportunities for improvement that must be implemented on that platform to enhance its performance within the framework of an IoT application for intelligent agriculture.

The present document is organized as follows: Section II presents the current state of the system, section III describes a few similar products available on the market, section IV outlines proposals for improvement, and section V presents conclusions and possible future lines of work.

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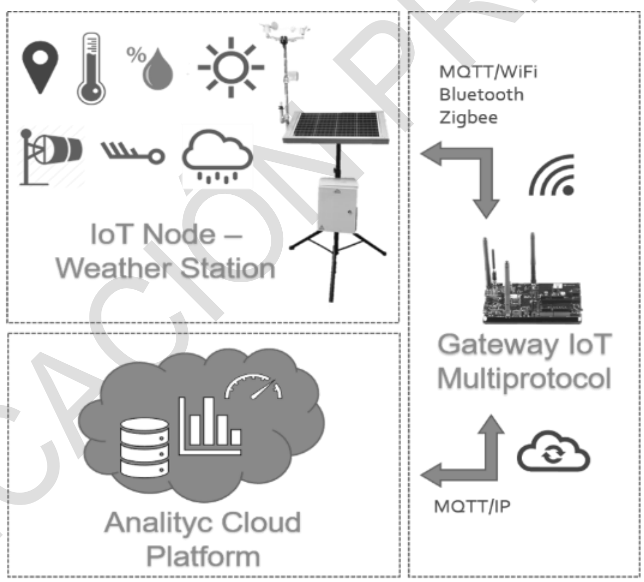
2. Functional Description of the PIICO Platform

The PIICO platform is based on the development of a multiprotocol gateway [21] and integrates a network of sensors and actuators, which are interconnected with three autonomous stations (wireless nodes), which are responsible for the two-way and simultaneous transmission of data collected from the outside, through Zigbee, Wifi and Bluetooth protocols to the Gateway. PIICO is a heterogeneous IoT communication platform, with the implementation of a multi-protocol gateway for internet connection and therefore can be adapted for multiple IoT applications in various fields.

Figure 1. PIICO's general architecture, operational description showing its main components: weather station type node, IoT multiprotocol gateway, and cloud analytics platform.



Source: own.

PIICO is currently being evaluated in an IoT scenario for agriculture where environmental variables are monitored. In this context of intelligent agriculture [20], three wireless nodes oversee the sensing of 6 environmental variables (humidity, temperature, wind speed, wind direction, radiation, and rainfall) and control two actuators (sprinkler and RGB LED). Besides, it publishes the outgoing data taken in JSON format to a public MQTT broker, where the cloud

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component subscribes to the broker and stores the information in a documentary database, the structure of the PIICO test scenario is shown in Figure 1.

The following is a functional description of each component:

2.1. Nodes

PIICO platform nodes are implemented on Raspberry Pi 3B boards. Scripts written in Python language are deployed to collect data from the mentioned variables and broadcast their outcome to the multiprotocol Gateway using wireless communication technology such as Zigbee, Wifi y/o Bluetooth. This is achieved by the execution of the program Station.py to which input arguments are added with the variable to be sent and the protocol to use, that program uses a format defined in another one called Json.py to structure the message to be transmitted to the Gateway as shown in Fig. 3. Also, each node has actuators for the activation of irrigation systems, and an autonomous energy source consisting of a battery with a charging system connected to a solar panel, as can be seen in Figure 1.

2.2. B. Gateway

The first version of the multiprotocol Gateway used by the PIICO platform was implemented on a Samsung Artik 1020 board, characterized by having multiple communication interfaces and being controlled by a Fedora-based operating system.

The Figure 2 shows that Gateway functionalities rely on running programs written in Python and Bash language. InicioAP.sh configures the Artik 1020 as an Access Point (AP) so that through NAT, it provides wireless internet access received by its Ethernet interface. Subsequently, to communicate with the nodes, the different communication protocols are enabled by running Server_wifi.py, Server_blue.py and Server_xbee.py programs simultaneously. Those programs are briefly described as follows: Server_wifi.py enables message reception via Message Queuing Telemetry Transport (MQTT) protocol, configures the

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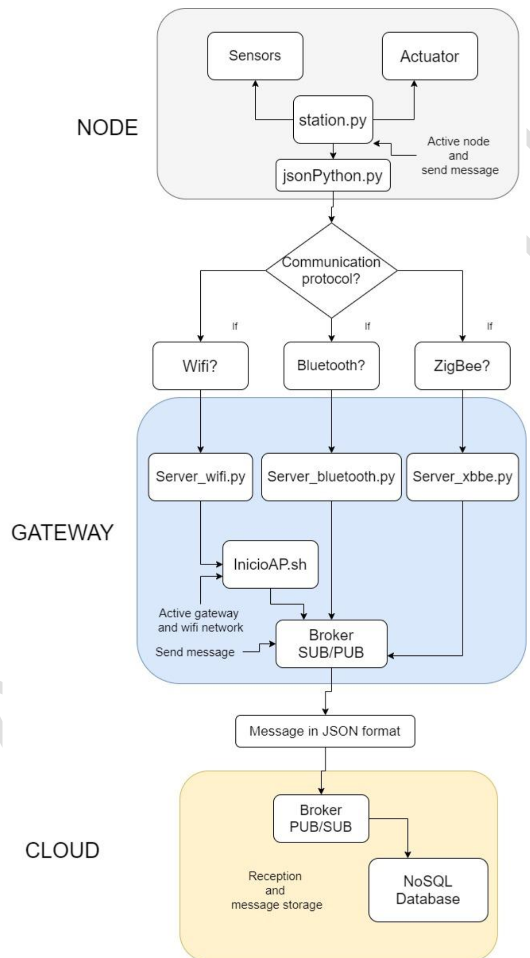
Gateway as a Broker, and defines public and private topics for managing two-way communication with nodes through the publisher/subscriber paradigm. Server_xbee.py script configures the Gateway as a Zigbee network coordinator, while Server_blue.py enables it to listen permanently for data coming from nodes previously paired with the Gateway via Bluetooth.

Figure 2. PIICO IoT gateway and node activation flowchart.



Source: own.

For sending and receiving data using the communication protocols described above, it is necessary to perform payload extraction of the structured JSON message on the nodes, where a message is generated for each variable. Figure 3 shows an example of the data sent in JSON format by some of the nodes.

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Regarding the transmission from the Gateway to the cloud component, a public and secure MQTT broker is being used; MQTT protocol is recommended for network scenarios in which bandwidth consumption should be reduced and where devices involved in communication have low processing and memory capacity. [20]

Figure 3. JSON formatted messages with data gathered by two nodes.


```
{
        "node-id": "nodo2"
        "gps":"-"
        "protocol": "wifi"
        "date": "09/12/19-08:59:18"
        "sensor-id": "Temperature"
        "value": "19.9"
        "magnitude": "Celsius"
        "gate-id": "-"
        "network-id": "-"
}
{
        "node-id": "nodo1"
        "gps":"-"
        "protocol": "Bluetooth"
        "date": "09/12/19-08:59:18"
        "sensor-id": "Humidity"
        "value": "48.2"
        "magnitude": "percent"
        "gate-id": "-"
        "network-id": "-"
}
```


Source: own.

2.3. Cloud-based Analytics Platform

The third component of PIICO is the Cloud analytics platform, this has databases responsible for saving the information generated by IoT nodes; Similarly, it has a Web Service that implements descriptive analytics and data processing models. Besides, there is an information visualization tool where the information generated by PIICO is classified. The analytics module supports two communication architectures, one of which is client/server type used with the nodes, and the other one is publisher/subscriber type employed with the Gateway, as shown in Figure 4, both processes are managed through a public MQTT broker. [22].

Currently, the PIICO platform has transactions through a public broker that allows the communication and data management of each node, and the analytical component generates

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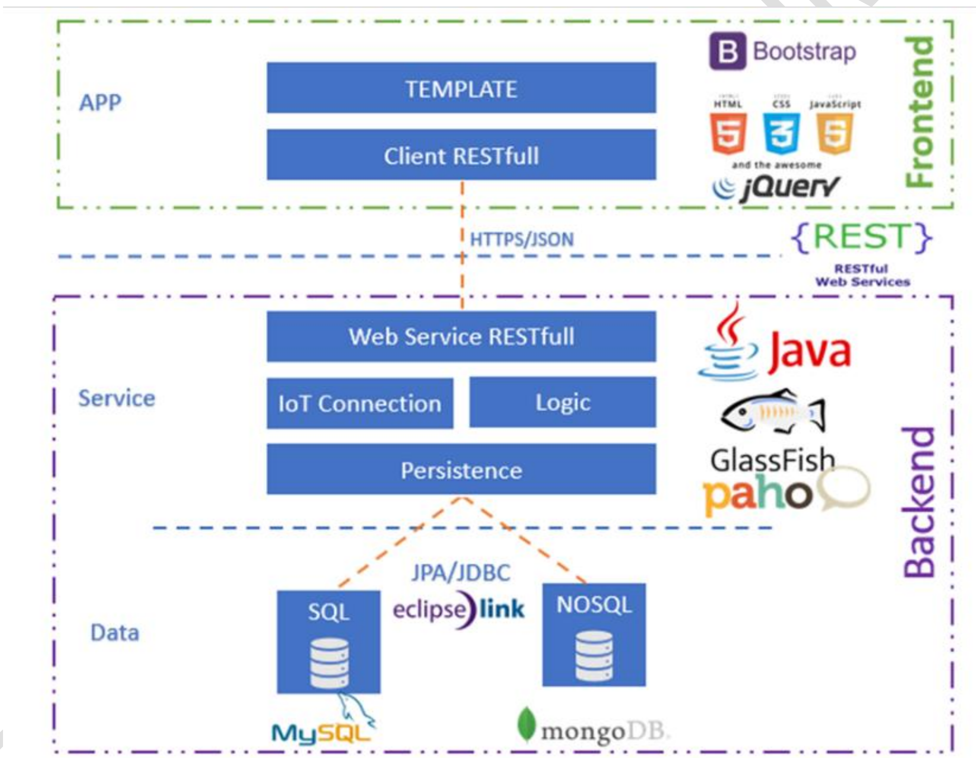
graphs for each node and variable. Although this task is true with the data delivered, it would be more convenient for these graphs to be generated in real-time and dynamically. Also, and because of previous work, the data stored on the server was generated by a simulator, which allowed the validation of a beta version of the analytical component developed for the PIICO platform [22]. However, it is necessary to do greater exploitation of data and implement several analytical models, to have the ability to provide personalized services. It is essential to continue in the development of this analytical component.

Figure 4. JSON formatted messages with data gathered by two nodes.



Source: own.

3. Similar Systems in the IoT Industry

On the IoT market, there are many products for monitoring environmental variables in scenarios like that of assisted agriculture developed in the PIICO project, these systems are characterized by being compact and because they collect data from various environmental variables simultaneously. Below there is a brief comparison between the components of the PIICO platform and some solutions available on the IoT market.

3.1. Nodes

The company ALLMETEO offers a helical climate station whose design favors maintenance of its sensors, allows collection of weather data with the possibility of transmitting using protocols such as, Sixfox, LoRa WAN. NBIoT and LTE-CAT-M1 [23]. On the other hand, the English company LEMKEN offers a portable weather station designed to be partially inserted on the site of cultivation, sensors are in its structure, but data transmission is done only through the SigFox protocol [24]. Even though there are commercial developments that have several operational functionalities, these are limited for expansions, either, they have proprietary communication protocols or because they are closed hardware platforms. One of the great advantages of PIICO IoT nodes over other environmental monitoring solutions is that they integrate a development-oriented open-source application with the functionality of handling actuators that allow having closed-loop control.

3.2. Gateway

A wide variety of Gateways are currently available on the market and some features provided by their fabricants must be highlighted; it is the case of the company NXP, which provide multiprotocol connectivity with Zigbee, WiFi, and Ethernet [25]. Another example is RIGADO's product, called "Cascade IoT Gateway" which employs Wifi, BLE, and GSM mobile networks [26]. Each development stands out for the multiple connection interfaces however, those products are packaged within a broad portfolio of complementary cloud analytics, storage and management services, which greatly limits the flexibility of these platforms when deploying with devices and systems developed by third parties.

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Concerning the PIICO IoT Gateway platform, it is important to note that due to the closure of Samsung's Artik project and service support discontinuity, it is necessary to replace this board with another that offers the processing, storage and multiprotocol communication capabilities similar to the currently available. That new board must also provide the flexibility of software development to facilitate the configuration and management of an IoT Gateway.

3.3. Cloud-Based Analytics Platform

There is a great variety of combinations between descriptive, predictive, or prescriptive analytical methods that allows the creation of more robust and powerful platforms for the analysis of data obtained by IoT devices. they can also have all types of analytics and provide parameterization types so that a custom platform can be created according to the analytics application [17]. An example of this is Google Big Query Analytics, which is a component or system of the Google Cloud Platform (GCP), which allows the creation of data storage space obtained from Big Data, where they go through filters that allow reaching the analytical processes. Depending on the type of analytics, they are saved in different locations or Storage. Google Big Query Analytics proposes a service for companies or groups that require to do analytical processes, regardless of the method you want to use, being a versatile and powerful tool, that provides capacity, speed, and good performance among other characteristics as well as its own analytics processes [27]. Other platforms are also intended for the IoT application market, such as Microsoft Azure IoT, Thing Speak, Eclipse IoT, among others [28]. These platforms, while providing suites for data storage and further analysis, are conditioned by agreements that prevent the distribution of results, limit the amount of information and IoT network management. Similarly, they do not allow a specific application in intelligent agriculture and it is not possible to generate actuator control services on IoT nodes.

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4. Result: Proposals to Improve the PIICO Platform

Based on the analysis of the current state of the PIICO platform and after the characterization of each of the components that make up the platform, it is evident the need to develop some software components and make some improvements to the system, which are presented below. The usability of the platform could be enhanced with a web application that allows the visualization real-time data, also, the remote management of PIICO components should be facilitated. In the proposed graphical interface, parameters such as the sensors sample rate, topics required for two-way communication via MQTT should be configured. The addition of new remote nodes could be facilitated as well as the configuration of Wifi, Zigbee, and Bluetooth networks. Additionally, the software component must be optimized to automate communication between nodes and Gateway.

Given the characteristics of a multiprotocol Gateway, administration from a graphical interface on the web could facilitate the adaptation of the PIICO platform to various IOT applications different to the context of intelligent agriculture on which the platform is currently being tested. With regards to the components of the PIICO platform, after analyzing different options and characteristics of commercial IoT components, several opportunities for improvement for the IoT nodes were identified, including the need to redesign the nodes structure to facilitate their transport and deployment, also the range of the communications interfaces must be enhanced to expand the coverage of the network. In addition to the above, it is necessary to improve the integration of the platform components, in the case of the nodes, it is possible to make changes in terms of the structure of JSON messages sent to the Gateway, all variables and measurements could be sent in a single message instead of one variable per message. Regarding the analytics component of the PIICO project, a platform redesign is required to

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orient it towards a descriptive analytics tool integrated with the IoT Gateway and devices connected to IoT nodes.

On the other hand, considering the closure of the Artik project and the interruption of technical support by the manufacturer, a study is proposed to select a suitable replacement thus considering the use of a single-board computer (SBC) implemented as a Gateway. The proposed study must consider, software design and development required for the management of the SBC, in such a way that the requirements and characteristics necessary for a multiprotocol gateway could be met. Besides, integration between, the database components, the acquisition of data from the public broker, and the use of the WEB service to perform analytics of acquired data is required.

Finally, in the review carried out for this article, it was found that it is possible to use many of the analytical tools in “on-premises” platforms, however, these present difficulties when making a remote connection, since endpoints and narrowed networks are required for the availability of information, which is why the idea of working with an analytical Cloud-based platform facilitates the connection, choosing a type of communication protocol will allow the transport of data. Several Cloud analytics platforms can be compared to each other, depending on the architecture, technologies, analytical methods, and connectivity; and example of this is to make a parallel between the analytical methods, which influences the topic of equations and algorithms that can be used to meet the type of analysis, either descriptive or predictive. When comparing the platforms, it is observed that the most relevant feature for their distinction is the process of data storage and type of analytics. On the latter, it is possible to use bases of Non-relational NoSQL database, which is responsible for saving information, not in specific places, but all are stored in a single point so filters can be applied to find specific data and move to the analytical algorithms, MongoDB being a NoSQL database with the best features to implement in the project.

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Analytics platforms are being applied in different environments, one of the most influential in the industry is marketing which by using descriptive analytics obtains relevant information about the taste of customers identifying patterns according to what happens or the way the customer interacts. This can be a great advantage since there is more control over the markets or potential customers by generating a more effective and proactive approach thus improving the interaction with them. This is just one of the many examples in the business sphere showing how powerful data analytics can be. Pertaining S-PIICO, by integrating the Cloud analytics platform with IoT devices, better control over agricultural areas can be achieved, from the descriptive analyses it is possible to identify crops conditions, allowing better monitoring in a remote and agile way to identify and manage problems accordingly.

5. Conclusions

Despite IoT's recent deployments, hardware/software developments are still required for the integration and interoperability of devices, communications networks, standards, and data analytics algorithms.

The implementation of the proposed improvements for the PIICO platform will ensure easier and more flexible platform management. It will also decrease the time required to deploy a practical application with the platform. Additionally, the proposed redesigns and updates would extend this platform’s operation in the long term so it can provide a valuable ground for the scalability of IoT applications bases on a multiprotocol Gateway.

The usefulness of having a data analytics platform was identified, as they may have different methods for this process with Big Data, such as descriptive analytics which can provide valuable information to understand the state of data sources, predictive methods that can generate decision-making options in business models, changes in infrastructure, among others. There are more methods of data analysis within the main and stronger are these two but, based

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on the analysis made it is recommended for the PIICO platform to implement a descriptive method.

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