Smart-IoT Platform to Monitor Microclimate Conditions in Tropical Regions

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Abstract. Precision farming has a large scale of applications including wireless sensor networks to monitor the crop yields. For example, Raspberry pi board enables the possibility to integrate the agriculture system with online servers as well as an efficient sensor method for monitoring agricultural parameters. The occidental region of Panama is an agro-based economy; for instance, precision farming can help the farmers use modernization techniques which improve primitive methods, still used in developing countries. However, commercial solutions of sensors are very expensive for farmers, making it impossible for small producers to implement this type of system. The purpose of this research is to present an updated comprehensive systematic literature in the field of IoT smart agriculture, showing a prototype of an IoT device and the monitoring system platform. The developed framework allows the control from a remote location and it can be implemented in grain stores, agricultural fields, and farming households.

1. Introduction
The Internet of Things (IoT) is a promising innovative technology that enhance the user’s perception and ability to modify the working environment with automation tools. IoT offers multiple solutions in different domains such as healthcare, retail, traffic, security, smart homes, smart cities, and agriculture. IoT deployment in agriculture is considered the ideal solution for continuous monitoring of a Controlled Environment Agriculture (CEA).

In recent years, many studies have been presented in IoT-based agriculture. Therefore, this kind of technology is constantly evolving and needs to be studied. Sustainable agriculture is required to support world population growth, climate change, water and natural resources preservation. The perspective of this transformation is supported by the European Commission (EC) [1]. To achieve a better agricultural productivity, it is necessary to foresee the yield of crops in a framework of a great variety of environmental conditions, soil, fertilization and irrigation, among others. Under the same data-gathering approach for crop yield it can also address issues such as climate change, resource constraints (water, labour and energy, etc.), and societal concerns around issues such as animal welfare, fertilizers and the environment that often affect agricultural production.

The most important production of the vegetables in Panama is located in the Western Region specifically in Cerro Punta, Chiriquí. Producers face challenges and risks due to weather conditions and market factors. Consequently, an effective management of the risks provided to the producer’s mitigation tools increases production. For this reason, using technologies can help mitigate these challenges. In the field of agriculture, IoT is used at different levels of the agriculture industrial production chain [2]. Below in (Figure 1) presents an IoT platform diagram.

Due to the rapid growth of science and technology, agriculture as a science has progressed at a gradual rate. To keep pace with modern technology, many of the agricultural producers and experts are turning to the IoT to attract advancements in the technological field. As for Panama, agriculture is one of the
important axes in the economy. However, the most important barrier in traditional farming techniques is climate change which can be addressed with emerging technologies.

Figure 1. IoT platform diagram

The contributions of this document related to the domain of IoT agriculture are as follows. Section 2 presents literary references on the Internet of Things applied to agriculture and on the type of data collected. Later, section 3 presents the design and implementation of the IoT Platform. Finally, section 4 shows the results and perspectives of this study.

2. Related Works

Different researchers have proposed different IoT-based technologies in the field of agriculture that are greatly increasing development in the field. There are also works on different agricultural projects based on smart farming to improve quality and productivity. Some IoT-based techniques have been identified from the literature, which have been summarized in this section.

In [3], the authors present a multi-tier architecture to address intelligent IoT-based monitoring, as well as an implementation of the architecture through multi-agent modelling of IoT devices for precision agriculture. Hung [4], proposed a system to monitor and control the humidity of the preventive maintenance plant in the different script locations. The system proposal consists of three components: (1) The perception layer consisting of the data acquisition module in the cloud which is used to obtain the sensor data; (2) The Wi-Fi component is used in the network layer to transfer the sensor data to the cloud application (3) The data collected in the cloud was applied in real time to alarm and notify for preventive maintenance. The real-time display panel for users monitors and performs the status of objects in the application layer.

Chien et al. [5], created a system based on Chen-Chien's greenhouse IoT system. The system hardware consisted in two parts: sensors/actuators and servers. The sensors include the measures of parameters such as temperature, relative humidity, luminosity, atmospheric pressure, a NoIR camera, and a thermal camera. The data collected from the sensors is stored in two repositories: one is in the database and the other is an expedient record. The data is stored in the form of a pair (key, value) in which customers can efficiently retrieve their relevant data. The logged data is automatically forwarded to a splunk indexer from which the users can efficiently explore the information.

The authors in [6], made use of a rice farm to measure humidity through the Node MCU ESP8266 microcontrollers and the SHT21 humidity sensor to send data to the Blynk server through a Wi-Fi network. A similar study proposes a monitoring system for soil moisture, temperature and water control through the use of NodeMCU ESP8266, sensors and Cloud Computing [7]. To study the effects of growth rate, production rate, crop planting water saving rate, the three methods were set, such as traditional farm, greenhouse by using a timer to control humidity from the soil and greenhouse by using sensors to automatically monitor the soil moisture experienced in the melon farm. The work in [8],
proposed an integrated system for monitoring the health of wheat crops. The main building’s blocks of the system consist in the IoT agri-nodes, a communication channel to transmit data, drones with a multispectral camera, a local server to archive the data and a web service to visualize the data. Another relevant study conducts an essential step for the use of optimization models and machine learning techniques [9]. The temperature data is obtained by a wireless sensor, and the metric comes from weather forecast service from different providers, showing the relative humidity of the air and the humidity of the soil.

In the same line, other works have developed smart agriculture IoT equipment to monitor environmental factors in a farm where the collected data was subjected to a 3D cluster analysis to produce an analysis of environmental factors [10]. The IoT equipment can detect air temperature, humidity, atmospheric pressure, soil moisture content, soil electrical conductivity, lighting, and soil salinity.

In [11], a model of an intelligent irrigation system is proposed to predict the water requirement for a crop yield by using automatic learning algorithms. Condensation, temperature and humidity are the three most essential parameters to determine the amount of water required in any agricultural field. The study in [12], a connected farm based on IoT is presented to provide intelligent agricultural systems for end users. The architecture includes three types of sensors to monitor environmental conditions, including an integrated sensor (temperature, humidity and CO2), a photosynthetic photon flux density (PPFD) sensor and a soil moisture sensor.

3. Design and Implementation

The evaluation of different types of emerging technologies is focused on the development of a monitoring platform, outlining the correct operation of resources and generating a new IoT data management mode. The interoperability functionality of IoT is based on various commercial or open-source platforms. For example, LinkSmart allows device identification, connection request processing and data subscription by type without having knowledge of the embedded systems hardware. Also, LinkSmart uses MQTT as its communication mechanism. On the other side, Kaaproject enables device inventory management and maintenance with real-time communication between devices. Its data agnostic transmission model promotes the structured and flexible use of the information collected. Kaaproject can be integrated into Android, IoS, Raspberry Pi, and other platforms. Data storage and processing can be carried out under some NoSQL solutions such as mongoDB, Hadoop, Cassandra. The Community Edition version of ThingsBoard is an open source and provides device management, data collection, processing and visualization.

We implement ThingsBoard, which uses SQL database and NoSQL, for the storage of data collected by IoT devices. The platforms analyzed allow connecting any device that can use the HTTP, Websockets, MQTT or CoAP protocols. Most of the features and add-ons of the platforms are in development mode, giving some integration problems with the Azure cloud, IBM Watson, AWS IoT, among others. The minimum interval of data transfer from the IoT device to the server is 1.61 milliseconds, while the longest connection interval is 10 milliseconds. ThingsBoard presents the results of data transfers versus the other open-source platforms studied with an average of 3.5 milliseconds of connection. The platforms studied are under the Apache 2.0 free software license.

The platform ThingsBoard works with an optimal performance. The IoT devices consist of integrating different components: Microcomputers (Raspberry PI), and micro sensors (Figure 2). With the use of Raspberry PI boards, the aim is to enhance the use of nodes with sensors to visualize the detection of environmental conditions that can be used in the automation of agricultural production processes. The latest version Raspberry Pi 4 has a much higher performance than its predecessor Raspberry Pi 3, however; it is not compatible with some libraries that will be used in this project. For this reason, the Raspberry Pi 3 and some Grove Pi components will be used.
In our project, the connection of a prototype with the server is made by GSM or WIFI communications to stream the time series data with the unit of measurement. The IoT platform allows real-time visualization of collected data. The farmer can select the same schedule for an hour, week or month. The designed system is flexible and scalable in terms of addition of new sensors. Also, the data collected is refreshed with a period of 15 minutes.

The essential parameters to be measured are temperature and humidity. These two parameters already allow us to make a climate balance and adapt production based on the results. In this way, the farmer could count on an IoT platform that provided information in real time, which help maintain optimal levels of production. The developed prototype as a solution for finding the most efficient monitoring way adapted to our climate conditions and realistic tools that we have access to.

4. Results and Perspectives

Currently, energy and environment management sectors are understanding and integrating the numerous benefits of the Internet of Things (IoT). The use of smart devices will allow farmers to predict climatic variations within the same plot and thus promote the waste amount reduction they produce, as well as the control of agricultural processes based on the weather, relative humidity, soil moisture, visible and UV-rays and other external factors. Those devices also allow the reduction of water quantity used to irrigate growing crops when they detect that the soil moisture levels are correct. The Republic of Panama is located in a tropical zone of the world, its temperature variations are relatively stable and vary during the year from 18°C to 35°C. However, these variations are more important with respect to relative humidity which depends a lot on the two main seasons in the country. In fact, the province of Chiriquí, like the rest of the country, enjoys dry and wet seasons. During the dry season, the relative humidity rate is low and remains on average below 70%. During the rainy season, the latter is above 85% for 8 months.

The main objective of this study is to check and assess the performances of the first prototype of the SmartAgri platform with the specific objective of comparing the microclimates of two nearby areas of the David district separated by a short distance. The monitoring platform developed is based on a Raspberry Pi 3 B+ microcomputer with Grove DHT11 sensors for temperature and relative humidity as shown in Figure 3.
The system has been installed on roof terraces with an interval of 20 minutes between each measurement during the wet and rainy season of April 2021. This preliminary analysis lasted over a short-term period of 3 days and 3 nights at the two sites located in similar environments (semi-urban) 5 km away from each other. The data was retrieved through the ThingsBoard platform. Figure 4 illustrates the comparisons of the average temperature and humidity. Site A had a temperature range between 20°C and 30°C, and site B between 26°C and 32°C, while the minimum humidity in site A had a value of 80%, and in site A low up to 73%. At the same time, a difference of 2°C to 6°C was observed between the two sites, in addition to a difference of more than 10% in relative humidity. The importance of measuring the microclimates of an area was demonstrated because there may be variations between these two despite being located a few kilometres apart. The consequences on crop yield can be felt if the areas that do not have the same exposure to the sun, if one is drier than the other, among others.
5. Conclusion
The potential of our Panamanian agriculture using emerging technologies is in development. In our regions, we have different soil textures and microclimate behaviour representing several challenges to design a prototype adapted to these conditions. The local farmers can be benefited by this implementation and may be extended to the entire country. The incoming real challenges are faced to the inter-networking ad-hoc nodes in an agricultural field and in the design of a resistant adaptable box for the microcomputer board. For the future work we plan to analyse our data with predictive models and machine learning algorithms.

6. References
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Acknowledgments
This work was made possible thanks to the support of the Sistema Nacional de Investigación (SNI-130-2018) and (FIED19-R1-003) of Secretaría Nacional de Ciencia, Tecnología e Innovación Senacyt-Panamá.