Sustainable prototype with IoT implementation for remote monitoring of *Apis mellifera* apiaries in maya regions of Campeche, Mexico

Protótipo sustentável com implementação de IoT para monitoramento remoto de apiários de *Apis mellifera* nas regiões maias de Campeche, México

Prototipo sustentable con implementación de IoT para el monitoreo remoto de apiarios de *Apis mellifera* en las regiones mayas de Campeche, México

DOI:10.38152/bjtv7n2-001

Submitted: Mar 01st, 2024
Approved: Apr 17th, 2024

Felipe Ángel Álvarez Salgado
PhD in Management Sciences
Institution: Tecnológico Nacional de México
Address: Calkiní Campeche, México
E-mail: falvarez@itescam.edu.mx

Carlos Alberto Decena Chan
Master in Mechatronics
Institution: Tecnológico Nacional de México
Address: Calkiní Campeche, México
E-mail: cadecena@itescam.edu.mx

Edwin Gerardo Acuña Acuña
PhD in Physics and Mathematics by University of Salamanca
Institution: Universidad Latinoamericana de Ciencia y Tecnología (ULACIT)
Address: San José, Tournón, Costa Rica
E-mail: eacunaa711@ulacit.ed.cr

Luz María Hernández Cruz
PhD in Projects
Institution: Universidad Autónoma de Campeche
Address: San Francisco de Campeche, Campeche, México
E-mail: lmhernan@uacam.mx

Diana Concepción Mex Álvarez
PhD in Projects
Institution: Universidad Autónoma de Campeche
Address: San Francisco de Campeche, Campeche, México
E-mail: diancmex@uacam.mx

Charlotte Monserrat de Jesús Llanes Chiquini
PhD in Management Sciences
Institution: Universidad Autónoma de Campeche
Address: San Francisco de Campeche, Campeche, México
E-mail: chmllane@uacam.mx

Ricardo Gómez Kú
Master in Science in Electrical Engineering
Institution: Tecnológico Nacional de México
Address: Calkiní Campeche, México
E-mail: rgomez@itescam.edu.mx

Pedro Said Heredia Arjona
Graduated in Mechatronics Engineer
Institution: Tecnológico Nacional de México
Address: Calkiní Campeche, México
E-mail: 6079@itescam.edu.mx

ABSTRACT
Currently, beekeeping activities are being abandoned in the Camino Real region, which encompasses the communities of Tenabo, Hecelchakán, Dzitbalché and Calkiní, where the Tren Maya railroad lines cross, impacting indigenous beekeepers by modifying the land usage of the territory in section 2, presenting great deficiencies in these practices that are fundamental for the economy of families. This article proposes the design of an Internet of Things (IoT) based monitoring station prototype, which will measure the following variables: humidity, indoor temperature, outdoor temperature, average population and whether the box is open or closed; the information will be acquired by sensors and sent to an ESP32 microcontroller. Three essential components are required for its operation: Installation of a LAN Network, development of the IoT prototype and the Mobile Application. The purpose of the study is to design and deploy the prototype in Apis Mellifera Apiaries using a quasi-experimental and descriptive methodology, destined to improve the production of apiaries in the northern region of the state of Campeche, providing beekeepers with timely information of the hives for effective decision making.

Keywords: precision beekeeping, *Apis mellifera*, monitoring, IoT.

RESUMO
Atualmente, as atividades apícolas estão sendo abandonadas na região de Camino Real, que abrange as comunidades de Tenabo, Hecelchakán, Dzitbalché e Calkiní, onde passam as linhas ferroviárias do Tren Maya, impactando os apicultores indígenas ao modificar o uso da terra do território na seção 2, apresentando grandes deficiências nessas práticas que são fundamentais para a economia das famílias. Este artigo propõe o projeto de um protótipo de estação de monitoramento baseada na Internet das Coisas (IoT), que medirá as seguintes variáveis: umidade, temperatura interna, temperatura externa, população média e se a caixa está aberta ou fechada; as informações serão adquiridas por sensores e enviadas a um microcontrolador ESP32. Três componentes essenciais são necessários para sua operação: A instalação de uma rede LAN, o desenvolvimento do protótipo de IoT e o aplicativo móvel. O objetivo do estudo é projetar e implantar o protótipo em apiários de Apis Mellifera usando uma metodologia quase experimental e descritiva, destinada a melhorar a produção dos apiários na região norte do estado de Campeche, fornecendo aos apicultores informações oportunas sobre as colmeias para uma tomada de decisão eficaz.

Palavras-chave: apicultura de precisão, *Apis mellifera*, monitoramento, IoT.

RESUMEN
Las actividades apícolas actualmente se encuentran en abandono en la región del Camino Real, que abarca las comunidades de Tenabo, Hecelchakán, Dzitbalché y Calkiní, por donde pasan las vías del Tren Maya, impactando a los apicultores indígenas al modificar el uso de

suelo del territorio de la sección 2, presentando grandes deficiencias en estas prácticas fundamentales para la economía de las familias. En este artículo se propone el diseño de un prototipo de estación de monitoreo basado en el Internet de las Cosas (IoT), que medirá las siguientes variables: humedad, temperatura interna, temperatura externa, población promedio y si la caja está abierta o cerrada; la información será adquirida por sensores y enviada a un microcontrolador ESP32. Para su funcionamiento se requieren tres componentes esenciales: la instalación de una red LAN, el desarrollo del prototipo IoT y la aplicación móvil. El objetivo del estudio es diseñar y desplegar el prototipo en apiarios de Apis Mellifera mediante una metodología cuasi-experimental y descriptiva, orientada a mejorar la producción de los apiarios de la región norte del estado de Campeche, proporcionando a los apicultores información oportuna sobre las colmenas para la toma de decisiones efectivas.

Palabras clave: apicultura de precisión, *Apis mellifera*, monitoreo, IoT.

1 INTRODUCTION

Mexico hosts a great diversity of native bee species; however, since its introduction, Apis Mellifera has had wide approval, being highly important both culturally and economically for thousands of Mexican families, and it has been much more studied than native bee species; research is still needed to provide both productive aspects from the generation of better databases about production, management, diseases, etc., and ecological aspects, such as their interaction with local fauna. They are great suppliers of honey, wax, pollen, propolis among other derivatives in the colony, coupled with their role as crop pollinators, aiding the ecological balance.

Many studies point to this important species for its contribution to the ecosystem considering the current global scenario, which includes climate change, alterations in land usage, pollution, among other aspects. The need for more ecological studies on Apis Mellifera in Mexico arises.

A major railway project taking place in Southeast Mexico: the Tren Maya, which involves deforestation for the construction more than 1,500 km of railroad track that will cross the states of Tabasco, Chiapas, Campeche, Yucatán and Quintana Roo, which will have twenty stations and 14 smaller stops. The work comprises 7 sections to complete the circuit that covers the entire Yucatan peninsula.

Section 2 of the Tren Maya crosses the northern part of the state of Campeche, including the municipalities of Tenabo, Hecelchakán, Dzibtbalché and Calkiní, where the main beekeeping activities of the Camino Real region take place.

Currently, the situation of the apicultural sector in the state of Campeche is being impacted by climate change, along with the construction of the Tren Maya, where the territory and land use are being adapted, forcing beekeepers to modify the traditional way of managing hives, and to visit their apiaries more frequently for better control. Monitoring makes it possible to establish priorities after data analysis, which reduces the number of visits by the beekeeper and helps to know how to act in order to anticipate climate change events.

Consequently, this project focuses on measuring physical variables and recording graphic data with the intention of minimizing the time invested in this activity, and to increase productivity in apiaries. Therefore, we seek to design a monitoring system using technology of 4.0 precision. Beehives can greatly benefit from this technological potential, since the monitoring will be in real time (IoT), providing valuable information throughout the year and allowing us to achieve proper decision making to improve productivity and profitability of the colony, as well as the optimization of beekeeping practices by saving time, moreover, reducing mortality of bees avoids the decline in the hive.

2 THEORETICAL FRAMEWORK

The state of Campeche ranks nationally as the second largest producer of honey. In 2016, it had a production of 5,834 tons, with a value of 196,591,520 Mexican pesos (US$10,529,069), and a production of 2.49 tons of wax, with a value of 172,100 Mexican pesos, equivalent to US$9,217 (SIACON, 2017). Honey production in the state of Campeche is one of the most important social and economic activities, since nearly 12,000 families in the rural social sector in the state of Campeche depend directly on it (SEMARNATCAM, 2013).

According to the data obtained by SIACON (2020), the central municipalities of this study: Calkiní and Hecelchakán, reached a production of 218.14 and 153.01 tons, contributing approximately 9.8% of the total production in the State.

In 2018, 8,226.11 tons were produced, with the highest production taking place in the municipality of Champotón with more than 2,000 tons, followed by Hopelchén with more than 1,900 and Campeche with more than 1,300 tons. Together, the three municipalities contributed 5,501.59 tons, accounting for approximately two thirds of the total. Calkiní and Hecelchakán, with 474.06 and 421.41 tons, contributed approximately 10.8% of the total.

In 2019, 7,520.36 tons were produced, where the municipality of Champotón remained as the largest producer with more than 2,000 tons, followed by Hopelchén with more than 1,700 tons and Campeche with more than 1,300 tons. Together, they contributed

5,189.78 tons, approximately 70% of total production. Calkiní and Hecelchakán, with 324.03 and 379.89 tons, contributed approximately 9.3% of the total.

In the northern zone, which includes the municipalities of Calkiní, Dzitbalché, Hecelchakán and Tenabo, production ranges from 140 to 890 tons, with a notable production variability due to natural phenomena that have been affecting the productivity of the beekeeping livestock subsector for a couple of decades.

Owing to the significant progress that has been made with technologies based on the internet of things, in 2017 (Silva, Alisson de lima) developed a system that allows remote non-invasive monitoring of beehives through the internet of things (IoT). This system is designed to reduce the manual inspection of the hive by monitoring the hive through the installation of a series of sensors and a wireless network that uses the HTTP (Hypertext Transfer Protocol) communication protocol to send and store the information in a database (Silva, 2017).

Consequently, it can be stated that IoT (Internet of Things) solutions have reached the beekeeping sector, Y. Lu and L. D. Xu, 2019 that IoT (Internet of Things) is a technology entering with force in the reality of people. All environments are involved, urban, industrial, office or home.

IoT is key to digital transformation, says José Luis Sampietro et al 2022. The digital transformation journey comes with many challenges, but it is necessary to start it and leverage the opportunities.

Similarly, Andressa Ribeiro de Mezquita et al. in 2020 developed an IoT-based tool for monitoring the temperature of beehives, this tool is based on readings of the internal and external temperatures of the beehive taken every 5 minutes by a DS18B20 sensor which collects the information and sends it through an ESP8266, a Wi-Fi module that connects and transmits the data for subsequent storage in a PostgreSQL online database service, which is responsible of providing the beekeeper with visualizations and updates in real time with the data collected from the different temperature sensors (Mesquita,Santana, sales and dos santos, 2020). Without the help of Iot and Industry 4.0 improvements, it would not have been possible to keep the infrastructures running.

Even before the pandemic, the most requested IoT technologies in companies were sensors (84%), data processing (77%) and cloud platforms (76%), according to data from ABINC (Brazilian Association of Internet of Things), software tools designed to support and facilitate work among employees, an activity known as Supported Cooperative Work (CSCW), according to Infraspeak (2020). Associação Brasileira de Internet das Coisas, June 13, 2020.

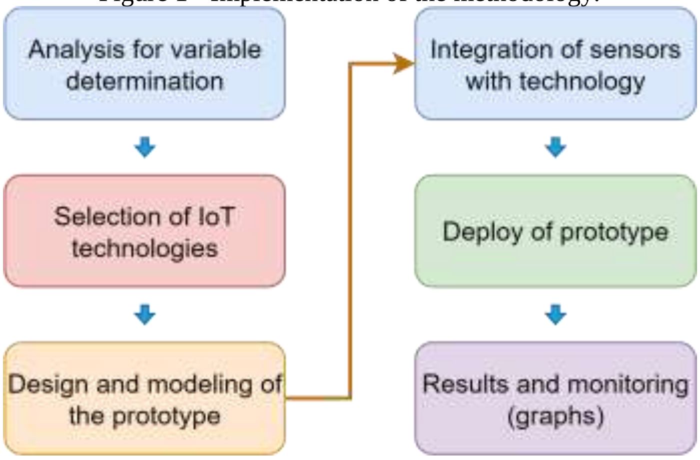
The prototype for remote monitoring of Apis Mellifera apiaries presented in this document is focused on the collection, storage and visualization of real-time data on variables such as humidity, indoor temperature, outdoor temperature, average population and open or closed box, parameters that can be used to study behavioral patterns or to know the status of the hive.

3 METHODOLOGY

The research was quasi-experimental. Subjects were previously selected with descriptive methodology, where individual behavior and different associated variables were observed for the registration of qualitative and quantitative data; this is located between the experimental research and the observational study, which is of utmost importance for applied research.

The methodology is composed of 6 stages, which cover from the problem definition and the selection of sensors to the integration and application of the system. Therefore, it presents a series of cyclical steps, i.e., it is constantly updated and there is always an opportunity to make considerable improvements derived from processes such as security and validation tests. It should be noted that this project covered all the stages proposed in the methodology for the design and construction of IoT systems for beekeeping monitoring.

Figure 1 - Implementation of the methodology.



Source: own author

In Fig. 1, the methodology is subdivided into six stages: Analysis for the determination of variables, Selection of IoT technologies, Design and modeling of prototype, Integration of sensors with technology, Implementation of the prototype, results and monitoring (graphs).

3.1 ANALYSIS FOR VARIABLE DETERMINATION

Based on the problems detected in the apiaries of the Camino Real region with the relevant data of Cruz, et al. 2022, which states that the socioeconomic and technical conditions faced by the beekeepers of the Yucatan peninsula have had considerable consequences in the productivity of their apiaries and, therefore, in the economic benefits they find in beekeeping (Güemes Ricalde, Echazarreta González, Villanueva G., Pat Fernández, & Gómez Álvarez, 2003).

The literature review has identified some variables already studied; such as those proposed by Loaiza, et al. (2022). However, here we have chosen to include the measurement of humidity, indoor temperature, outdoor temperature, average population and whether the box is open or closed; which will be studied for the first time.

La adopción de herramientas de monitoreo de servidores es crucial para garantizar

3.2 SELECTION OF IOT TECHNOLOGIES

Based on the variables to be measured, it will be necessary to identify the appropriate sensors that allow the reading in the conditions of an apiary; these are generally associated with the phenomena that affect the colony, the state of health of the bees, as well as honey production.

3.3 DESIGN AND MODELING OF THE PROTOTYPE

For this stage it is necessary to design each part of the prototype structure using CAD modeling software (SolidWorks). The materials to be used require the necessary resistance since it will be exposed to air, sun and rain.

3.4 INTEGRATION OF SENSORS WITH TECHNOLOGY

The components will be assembled directly in the ESP-32, since it includes a camera module, SD card reader, together with Bluetooth and Wi-Fi technology, which allow the integration of the required sensors.

3.5 DEPLOY OF PROTOTYPE

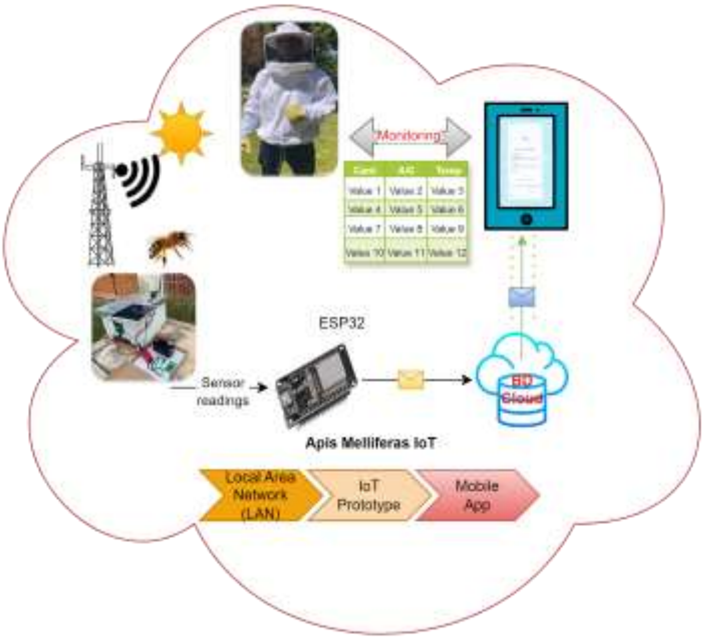
Once the components have been tested, they will be placed in the hive for reading and transmitting the data according to the study variables.

3.6 RESULTS AND MONITORING (GRAPHS)

The results are presented in graphs shown in the mobile application, which will be explained in the final part of this paper.

The stages of the development of the prototype for the record and reading of the variables involved in beekeeping are shown in Fig. 2 Diagram of the project stages, which seeks to meet the main objective of the monitoring system for beekeeping variables.

Figure 2 - Schematic diagram of project stages



Source: Designed by Felipe Álvarez, 2024.

The general architecture of the module is presented in Figure 2, where it is shown how the sensors take the relevant information from the beehive to then be sent to the database manager hosted in the cloud where the web service interprets the variables through the mobile application to later generate graphs and present them to the beekeeper as statistics.

Through this design, the functionality is conceptualized and divided into three large blocks: LAN Network, IoT Prototype and the Mobile Application, and the different requirements necessary for the proper operation of the system are identified. These include the selection of the variables to be captured in the apiary, the selection of a microcontroller and the different sensors that are in charge of collecting data from the readings to determine the humidity, indoor temperature, outdoor temperature, average population and whether the box is open or closed. The data is sent from the ESP8266 Wi-Fi module to the database manager and the web service for its interpretation and visualization by the mobile app.

Adopting server monitoring tools is crucial to ensure stability, security and efficiency of a company's information technology systems. These tools offer a series of advantages ranging from early detection of problems to optimization of available resources, indicates Raúl Chiullo, et al. 2024.

The communication layer with the NodeMCU device is conformed by a REST API service developed in PHP with the Laravel 10 framework and a MySQL 8.0.1 database. These services are hosted in the Microsoft Azure cloud using the WebApplication and Azure SQL Database services. This layer receives the data collected by the device. And it is presented to the client through the Metabase BI application, allowing the collected data to be graphed for analysis.

4 MCU SELECTION

The microcontroller used is the ESP-32, since it allows the integration of a camera module, an SD card reader, as well as Bluetooth and Wifi Technology. Moreover, one of its features is the ability to operate independently, likewise, it performs tasks without physical cables and is a viable device for IoT solutions (Brandão, 2019).

Table 1. Main Characteristics of the ESP-32 device.

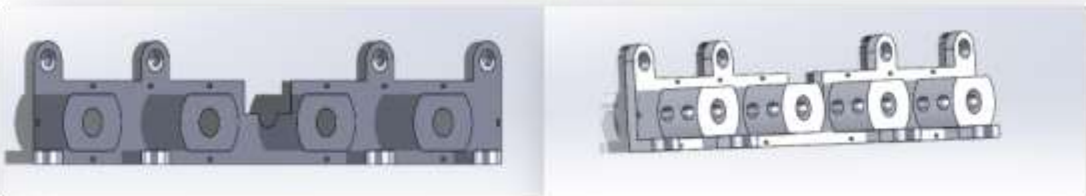
Device	ESP-WROVER	ESP32-DevKitc	Ai-Thinker
CPU	Two-Low Power Xtensa® 32-bit LX6	Dual Core Xtensa®	Dual Core Xtensa®
Flash Memory	4MB	4MB	520KB + 8MB PSRAM
Clock speed	80-240[Mhz]	160-240 [Mhz]	160-240 [Mhz]
Input	3.3 – 5 [V]	3.3 – 5 [V]	3.3 – 5 [V]
Micro USB connector	Type A, Type B	Type B	-
Wi-Fi Protocol	802,11 b/g/n/e/i	802, 11 b/g/n/e/i	802, 11 b/g/n/e/i
Wireless Security Protocols	WPA/WPA2/ WPA2-Enterprise/WPS	WPA/WPA2/WPA2-Enterprise/WPS	WPA/WPA2/WPA2-Enterprise/WPS
Bluetooth Connection	Bluetooth v4,2 BR/EDR,Low Energy BLE	Classic BT, Low Energy BLE	Classic BT 4.2 BR/EDR, BLE
Software compatibility	ESP-IDF	Arduino IDE, ESP-IDF,ESP-ADF, Eclipse	Arduino IDE, ESP-IDF, Platformio
Price	40 USD	15 USD	27USD
Dimensions	18*31*3,3[mm]	55*28*12,3[mm]	27*40*3,3[mm]

Source: Authored by Carlos A. Decena, 2024.

5 DIGITAL DESIGN OF THE 3D PROTOTYPE

The prototype is required to be in outdoor situations. Therefore, its design was made in the SolidWorks CAD software. This allowed us to make the model for a protective frame, which will isolate the device from climatological factors (water, dust, sun):

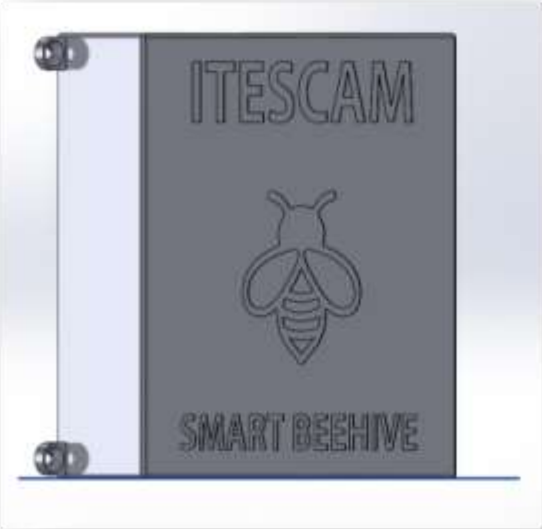
Figure 3 - Entrance/Exit Design.



Source: own author

At first, the frame was made to hold the infrared sensors Fig. 3, each sensor is located in front of a photoreceptor and each one of them is 5mm. The bees pass through the center that has a diameter of 10 mm to avoid making the passage too large, which could cause false or null readings.

Figure 4 - Protective case



Source: own author

The last element of the frame, Fig. 4, is the protective case for the sensors and internal connections. The figure shows the frame with the case, where the access ducts protrude slightly, while the rest is covered.

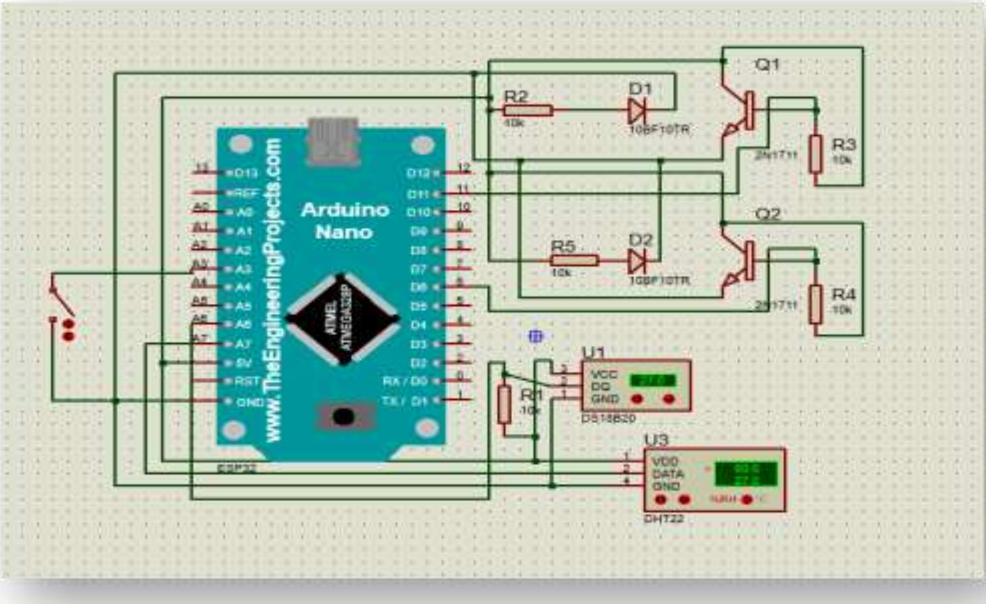
For the internal connections to the microcontroller, a box was designed with small outlets for the cables to avoid damage due to humidity or external factors.

6 PCB BOARD DESIGN AND ASSEMBLY

Furthermore, the design of the connection of the devices was carried out with the Proteus 8 professional software, which allows the creation of electronic diagrams shown in Fig. 5.

ISSN: 2595-5748

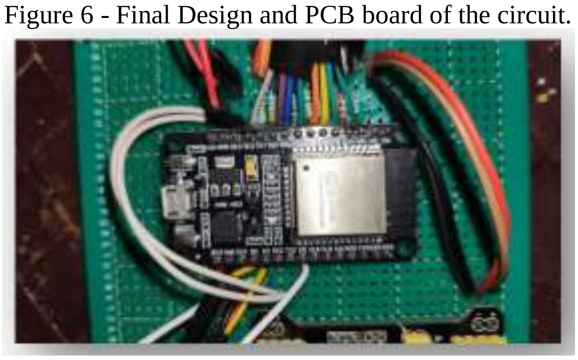
Figure 5 - Schematic diagram of device connections.



Source: own author

Moreover, Fig. 5 shows that the design of the printed circuit has different stages, an essential part of this design is the power supply, considering the need of low energy consumption to ensure portability. It is worth mentioning that the design of the PCB board has dimensions 6mm*8mm in which several devices must be attached, such as resistors, voltage regulators etc.

Figure 6 - Final Design and PCB board of the circuit.



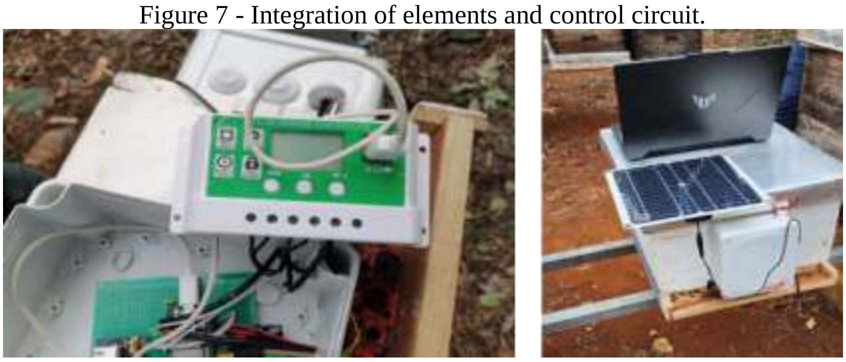
Source: own author

A battery, a solar panel and its voltage regulator were used to power the outdoor circuit as shown in Fig. 6. The internet signal was obtained from another project that was worked on at the same time with an antenna to provide WiFi in remote locations.

7 CONTROL CIRCUIT AND INTEGRATION ELEMENTS

A small 1W panel was enough to power during the day the 12V battery which in turn powers the microcontroller battery.

Figure 7 - Integration of elements and control circuit.



Source: own author

As shown in Fig. 7, the design was made by integrating the elements for the operation of the remote monitoring prototype in Apis Mellifera Apiaries.

The sensor is placed in the external part of the hive, one of its parts is in the lid and the other is attached to the box. The software development is presented in Fig. 8, which manages the interaction of the user with the module. The data transfer is done through an API. The router captures the signal and transmits it with the SSID and password to the esp32 board. The sensor variables, stored in the temporary memory of the board, are sent every 15 minutes over the internet to a server in JSON format.

The following Arduino code is used to convert and create the data sequence:

Figure 8 - Integration of elements and control circuit.

```
    http.begin(client, serverName);

    http.addHeader("Content-Type", "application/json");
String data = "{\"device_id\":\"" + String(id) + "\"," +
              "\"temperatura_int\":\"" + String(temperatura_int) + "\"," +
              "\"temperatura_ext\":\"" + String(temperatura_ext) + "\"," +
              "\"humedad\":\"" + String(humedad) + "\"," +
              "\"poblacion_med\":\"" + String(poblacion_med) + "\"," +
              "\"caja_oc\":\"" + String(caja_oc) + "\"}";

              Serial.println(data);

    int httpResponseCode = http.POST(data);
```

Source: own author

The data structure is simply recreated by replacing the values with the sensor variables. Through HTTP communication the server hosted in AzureWebsite"is requested to publish with the protocol shown in fig. 8.

Figure 9 - Internet antenna installation.

Source: own author

As a result, the implementation of the remote monitoring prototype in apiaries of Apis Mellifera in a Maya region, shown in fig. 9, was successfully placed in the hive to carry out the measurement of the variables.

Figure 10 - Commissioning of the IoT Prototype

Source: own author

8 RESULTS

The measuring of variables has allowed us to track the behavior of the colony, visualizing changes in the records of humidity, interior temperature, exterior temperature, average population and open or closed box in the mobile application. This gives the beekeeper relevant information to know what is happening in the ecosystem of the apiary.

Figure 11 - Prototype and interface testing

Source: own author

Figure 11 shows the graphs that present metrics according to the daily readings. Fig. 11 (a) internal temperature inside the hive, (b) external temperature, (c) humidity inside the hive, (d) colony population. However, these parameters must be interpreted according to the beekeeper's experience to associate the behavior to indicators that trigger or not an alert.

Figure 12 - Performance test results

Source: own author

9 CONCLUSIONS

Precision beekeeping is an alternative solution for producers in the northern Maya region of the State of Campeche for adding value to their beekeeping activity by leveraging the technification of apiaries that facilitate the activity's daily tasks, such as tracking the behavior through permanent monitoring supported by Internet of Things (IoT) technology. The study has determined that the implementation of prototypes that support the sector is functional, since decision making will be more assertive and timely, allowing quick action in case alerts are detected in Apis Mellifera colonies. It is recommended to propagate this type of innovation by promoting investment that detonates a continuous improvement in honey production.

REFERENCES

Arteaga-Quico, Alisson Diane, & Wong-Portillo, Lenis Rossi. (2021). Framework para el monitoreo de la temperatura de cultivos acuícolas basado en IoT. DYNA, 88(218), 239-246. Epub March 29, 2022.https://doi.org/10.15446/dyna.v88n218.90626

CARVALHO, B., ALCÁNTARA, G., PARREIRA, P., JUINIOR, R., & VINICIOS, F. (2018). Implantação do programa 5S a través da metodología DMAIC" publicado en Brazilian Journal of Development. *Brazilian Journal of Development [en línea]. Brasil*, *4*(5), 2163-2179.

Cetzal-Ix, W., Noguera-Savelli, E., & Martínez-Puc, J. F. (n.d.). Flora melífera de la península de Yucatán, México: Estrategia para incrementar la producción de miel en los periodos de escasez de alimento de Apis mellifera L. Cicy.Mx. Retrieved March 28, 2024, from https://www.cicy.mx/Documentos/CICY/Desde_Herbario/2019/2019-09-05-Cetzal-Noguera-Martinez-Flora-melifera-de-PY.pdf

Chan Chi, José Reymundo, Caamal Cauich, Ignacio, Pat Fernández, Verna Gricel, Martínez Luis, David, & Pérez Fernández, Alberto. (2018). *Caracterización social y económica de la producción de miel de abeja en el norte del Estado de Campeche, México*. Textual: análisis del medio rural latinoamericano, (72), 103-123. https://doi.org/10.5154/r.textual.2017.72.007

Chi Chan, M. T. d. J. (2022). *Socioeconomía de los apicultores indígenas mayas camino real Campeche, México*. Lollalty Moreno de Cuvillier.
(N.d.). Com.Br. Retrieved February 25, 2024, from https://ojs.brazilianjournals.com.br/ojs/index.php/BJT/article/view/45140/33783

Márquez Echavarría, J. P., Loaiza Rodríguez, J., Gómez Cano, M., & Álvarez Gaspar, C. A. (2022). Sistema de monitoreo de un apiario basado en el internet de las cosas. Encuentro Internacional de Educación en Ingeniería.

(N.d.). Com.Br. Retrieved February 25, 2024, from https://ojs.brazilianjournals.com.br/ojs/index.php/BJT/article/view/45140/33783

Neto, M. de O., & Toledo, L. F. R. B. (2021). *Estudo da Aplicação dos Filtros de Partículas e Filtro de Kalman Estendido em Dados de Sensores RADAR e LIDAR / Study of the Application of Particle Filters and Extended Kalman Filter in RADAR and LIDAR Sensor Data*. Brazilian Journal of Technology, 4(4), 145–154. https://doi.org/10.38152/bjtv4n4-002

Salgado, F. A. A., Lara, C. O. C., López, C. J., Cauich, D. A. D., Herrera, L. A. C., Moreno, M. M., Aguirre, G. M. Q., & Kantun, D. A. A. (2024). Implementación de Redes LAN en áreas remotas, para comunicar apiarios de Apis Melliferas en zonas mayas de Campeche usando prototipos IoT. Brazilian Journal of Technology, 7(1), 82–95. https://doi.org/10.38152/bjtv7n1-006

Silva, R. C., Dill, T. L. T., Oliveira, S. A. B. de, & Piffer, D. M. (2024). Ferramentas de monitoramento da eficiência de servidores. Brazilian Journal of Technology, 7(1), 135–163. https://doi.org/10.38152/bjtv7n1-009