

Development of an IoT Tool for Optimizing Humidity Control in Cocoa Cultivation.

Desarrollo de una herramienta IoT para optimizar el control de la humedad en el cultivo de cacao.

Desenvolvimento de uma ferramenta de IoT para otimizar o controle de umidade no cultivo de cacau.

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Summary. - The following document presents the development of a humidity sensor for cocoa crops using IoT and Arduino. Its purpose is to showcase the various applications that new technologies can offer, particularly in the cocoa industry. It involves designing a humidity sensor node to measure changes in humidity and temperature using the electronic design tool Proteus. The measurement module is programmed in Arduino IDE and connected to the cloud via IoT, incorporating Node-RED as a means to remotely visualize real-time results. This is achieved through a presentation dashboard as the final output of the measurement process, collecting data on climate changes received by the transducer and comparing them with data obtained from the web over a specified period. This process verifies the sensor's efficiency and data accuracy, setting a precedent for future research in applied electronics, IoT, and telecommunications.

Keywords: 1; IoT 2; Arduino IDE 3; Proteus 4; Node-RED 5; Transducer.

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Resumen. - El siguiente documento presenta el desarrollo de un sensor de humedad para los cultivos de cacao utilizando IoT y Arduino. Su propósito es mostrar las diversas aplicaciones que las nuevas tecnologías pueden ofrecer, particularmente en la industria del cacao. Implica el diseño de un nodo del sensor de humedad para medir los cambios en la humedad y la temperatura utilizando la herramienta de diseño electrónico Proteus. El módulo de medición está programado en Arduino IDE y se conecta a la nube a través de IoT, incorporando Node-Red como un medio para visualizar de forma remota los resultados en tiempo real. Esto se logra a través de un tablero de presentación como la salida final del proceso de medición, recopilando datos sobre los cambios climáticos recibidos por el transductor y comparándolos con los datos obtenidos de la web durante un período especificado. Este proceso verifica la eficiencia y la precisión de los datos del sensor, estableciendo un precedente para futuras investigaciones en electrónica aplicada, IoT y telecomunicaciones.

Palabras clave: 1; IoT 2; Arduino IDE 3; Proteus 4; Node-RED 5; Transductor.

Resumo. - O documento a seguir apresenta o desenvolvimento de um sensor de umidade para culturas de cacau usando IoT e Arduino. Seu objetivo é mostrar as várias aplicações que novas tecnologias podem oferecer, principalmente na indústria de cacau. Envolve o projeto de um nó do sensor de umidade para medir alterações na umidade e temperatura usando o proteus da ferramenta de design eletrônico. O módulo de medição é programado no Arduino IDE e conectado à nuvem via IoT, incorporando o nó-vermelho como um meio de visualizar remotamente os resultados em tempo real. Isso é alcançado através de um painel de apresentação como a saída final do processo de medição, coletando dados sobre alterações climáticas recebidas pelo transdutor e comparando -os com os dados obtidos da Web por um período especificado. Esse processo verifica a eficiência do sensor e a precisão dos dados, estabelecendo um precedente para pesquisas futuras em eletrônicos aplicados, IoT e telecomunicações.

Palavras-chave: 1; IoT 2; Arduino IDE 3; Proteus 4; Node-RED 5; Transdutor.

1. Introduction. – The humidity in the agricultural sector generates many issues in cocoa cultivation, affecting its growth and production, which can lead to a 60% loss for the producer. One of the difficulties that arises is flat terrain with prolonged and heavy rainfall, leading to waterlogging, which hinders the cocoa's optimal development [1].

According to the Qantu Yachay Scientific and Technological Research Journal in its article 'Production and Export of Ecuadorian Cocoa and the Potential of Fine Cocoa,' it is mentioned that there is an annual export growth rate of 7.24%, positioning Ecuador as the fourth-largest cocoa producer globally, representing a 168% growth in the last 10 years. Meanwhile, production has shown an increase ranging from 16% to 60% in the last 5 years [2].

Since the farmer lacks knowledge of the necessary technology needed to facilitate their work, inconveniences arise when weather precipitations occur. It is important that, through technology, a tool is provided to control crop humidity without major incidents. The advancement in electronics has enabled their application in various fields of study, increasing their significance in the field and yielding significant results.

The general objective is set as the development of a technological tool for measuring humidity in crops, and the specific objectives include the analysis of information related to the development of sensors through code development programs, electronic design, and web connectivity. Likewise, determining the recommended characteristics of the components to be included and ultimately designing a real-time humidity sensor node.

This research utilizes Arduino IDE, an open-source platform for creating applications compatible with various Arduino boards. It combines Proteus for electronic design and Node-RED for cloud connectivity and result visualization. This development facilitates real-time humidity monitoring through a sensor, offering accurate data for informed decision-making in various scenarios.

Leveraging ICT and IoT alongside open-source software like Arduino IDE, we will advance a real-time cocoa cultivation humidity sensor node. This solution, grounded in networking and electronics expertise, ensures system accuracy and effectiveness for farmers' benefit. With IoT implementation and a connection module, data captured by the sensor is automatically and remotely transmitted to the cloud. Subsequent visualization and analysis yield insights into weather changes and precipitation, enhancing precision in addressing crop cultivation challenges.

This information will enable a more precise and effective approach to controlling and managing solutions to address various challenges that may arise in cultivation, thus ensuring informed decision-making and optimal agricultural process management.

2. Method. - Our methodology is structured to align with specific objectives, embracing an experimental approach. We'll begin by identifying cocoa crop loss percentages due to humidity, study ideal parameters, and proceed to develop, design, and configure the sensor node using Proteus. C++ programming in Arduino IDE follows, and Node-RED facilitates cloud connectivity. Our implementation involves humidity sensors, electronic components, and rigorous analog and digital fundamentals.

The advantage of using these devices is that they require a 5V power supply, making them one of the best options due to their low energy consumption. The sensor used for measurements is the DHT11, a temperature and humidity sensor. This sensor is one of the most efficient on the market, providing high reliability in its measurements [3].

The system operates within a local network, specifically the WIFI module, allowing strategic sensor placement for accuracy. The ESP automatically connects to a predefined network in its programming to ensure proper functionality.

Optimal sensor node performance relies on precise coding in Arduino IDE, the project's logical core. Custom code is vital for accurate and efficient data processing, guaranteeing real-time effectiveness for the cocoa crop humidity sensor node.

2.1. Relative Humidity and Data Efficiency. - Cocoa plays a vital role in Ecuador's economic development, and it has strong historical and economic ties to the country. Ecuador ranks as the second-largest cocoa-producing nation, covering approximately 24% of cultivated hectares [1]. Cocoa crops thrive under standard conditions with relative humidity ideally ranging between 70% and 85%. Going beyond this range can invite crop diseases. Temperature is another critical factor, with the optimal range typically falling between 18°C and 32°C, varying based on the geographical location [4].

This design hinges on precise data, essential features, and historical humidity data, offering a solid foundation for maintaining consistent control of relative humidity in crops. Relative humidity is calculated as a percentage of saturation humidity relative to the density of saturated vapor [5]. For study purposes, the following model is established as the calculation of relative humidity, indicating the grams of water per cubic meter of air. As considered in Equation 1.

$$HR = \frac{x = \text{Actual vapor density}}{x_{\text{sat}} = \text{Saturated vapor density}} * 100 \quad (1)$$

Where:

HR = Calculation of relative humidity

X = Absolute or actual vapor density

X_{sat} = Maximum (saturation) humidity

There is another fundamental parameter that allows for establishing an appropriate criterion to evaluate the sensor's performance through relationships and comparisons [6]. This parameter is known as efficiency, and its calculation is based on data or values obtained, as shown in Equation 2.

$$V = \frac{V_{\text{maxc}} - v_{\text{minc}}}{V_{\text{maxc}}} * 100\% \quad (2)$$

Where:

V = Sensor efficiency

V_{maxc} = Maximum data value in comparison

V_{minc} = Minimum data value in comparison

2.2. Humidity Sensor Node. - The proposed prototype is designed and simulated using Proteus 8 Pro, a digital design tool ideal for the real-time cocoa crop humidity sensor node. It provides essential components for this prototype. Arduino IDE, an open-source software, is used for coding the humidity sensor's logic, which is later integrated into the electronic design of the prototype, ensuring the device functions as intended. Subsequently, a block flow is created using the Node-RED tool to establish communication between the device and the cloud for data visualization, applying IoT [7].

Next, the block diagram of the prototype is presented, which represents a real-time humidity sensor node designed for implementation in cocoa cultivation. This representation outlines the various components that make up the project, with the aim of providing a clear and precise understanding. For a clearer visualization, you can refer to Figure I accompanying this description.

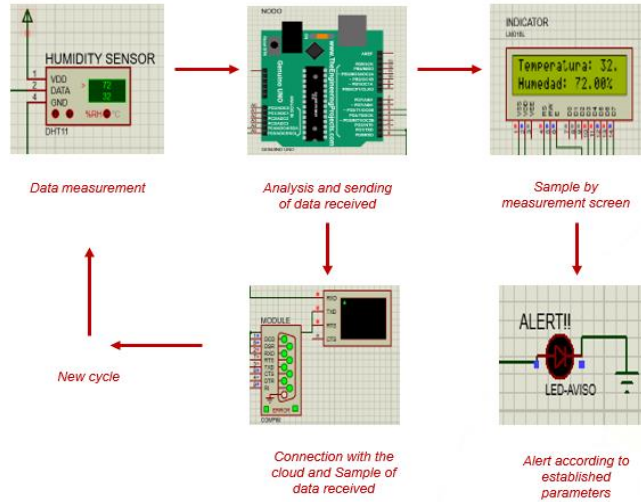


Figure 1 - Prototype process diagram

2.3. DHT11 Sensor in the Prototype. - The DHT11 humidity sensor measures the relative humidity index of the crops, providing a direct means of measurement [8]. The proposed prototype is designed and simulated using Proteus 8 Pro, a digital design tool ideal for the real-time cocoa crop humidity sensor node. It provides essential components for this prototype. Arduino IDE, an open-source software, is used for coding the humidity sensor's logic, which is later integrated into the electronic design of the prototype, ensuring the device functions as intended. As seen in Figure II.

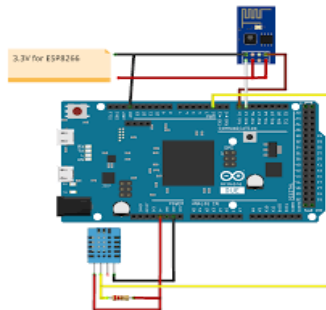


Figure II - Connection of Humidity Sensor Node

It is worth noting that it is also possible to establish a direct connection between the DHT11 sensor and the ESP8266 WIFI module, provided that no other electronic components are required for the prototype. As illustrated in Figure III.

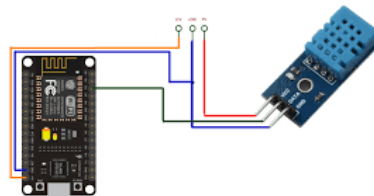


Figure III - Connection of DHT11 with ESP8266

Furthermore, the module communicates directly with the network, reaching various endpoints. As illustrated in Figure IV.

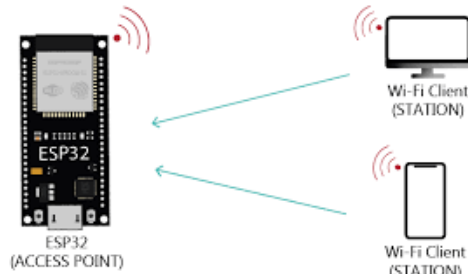


Figure IV - Module communication to the world

2.4. ESP8266 (COMPIM) and its application. - The ESP modules are wireless communication devices designed to connect a variety of electronic equipment to the cloud, enabling real-time sampling of relevant information and addressing specific needs. These modules play a key role in the expansion of the Internet of Things, as they facilitate service automation and have become a prominent trend in the growth of this technology [3].

For the present project, a digital device that acts as an ESP8266 module is applied, referred to as COMPIM in Proteus, serving as the connection medium to the cloud for the sensor node. As shown in Figure V.

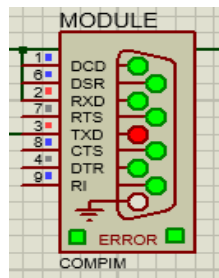


Figure V – Wi-Fi module ESP (COMPIM)

The device connects to the UNO board, receiving data from the DHT11, which is then transmitted to the cloud. Virtual Serial Port, an emulator of COM ports, is employed to create specific ports with various functionalities, enabling connectivity between devices when physical ports are limited in number [9][10].

Its application within the world of sensors is to facilitate the connection of the physical part, measurement of parameters with the Internet of Things (IoT), in order to provide the user with a data interface and results established over time, whose visualization helps in forming criteria for the various ongoing processes.

2.5. Introduction to IoT. - The Internet of Things is based on specific devices, technologies, and concepts that refer to the idea of providing connectivity and intelligence to a multitude of devices capable of communicating through the Internet.

In other words, it can be defined as a global infrastructure for the information society that provides advanced services through the interconnection of objects (both physical and virtual) due to the multifunctionality of ICT and communications [11]. This reference is illustrated in Figure VI.

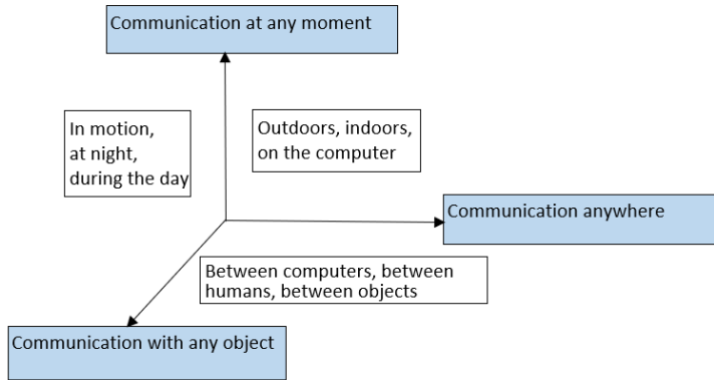


Figure VI – Internet of Things

Finally, it is mentioned that, as indicated in the image above, it can be observed that objects in the world, whether physical or virtual, are integrated into networks that allow information to be connected [11].

2.6. Communication of the Wi-Fi Module with the Cloud. - The ESP8266 Wi-Fi module, or COMPIM (simulation), provides the possibility to transmit any information it receives to the cloud. To achieve this, it is necessary to define a server that manages this data and can subsequently present it to end users. The COMPIM can also be defined as a physical port simulator, meaning, as mentioned earlier, it receives data and uploads it to the cloud. Therefore, it is indicated that it fulfills the parameters offered by any Wi-Fi module [12][13].

To achieve this, the use of the Virtual Serial Port program is necessary, which enables serial ports that, when configured, work directly with Proteus to establish the path or direction that the measured information will take. To establish the connection, two serial ports must be provided, creating a pair of virtual ports (COM1 and COM2) for transmission and reception, respectively, as shown in Figure VII.

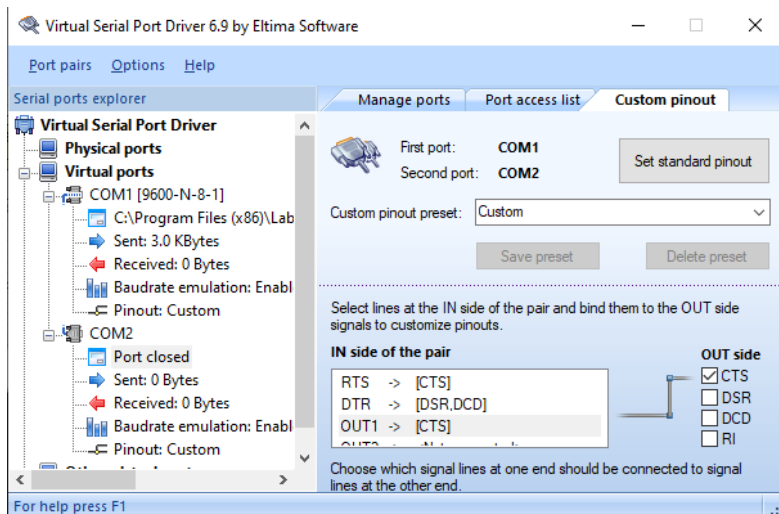


Figure VII – Creation of virtual ports

Once the virtual ports are created, the COMPIM module is configured in Proteus, specifying the port through which the data measured by the DHT11 is sent. This part is crucial, as without the correct configuration, there will be no communication. As mentioned, the COM1 port functions as the transmission port, as shown in Figure VIII.

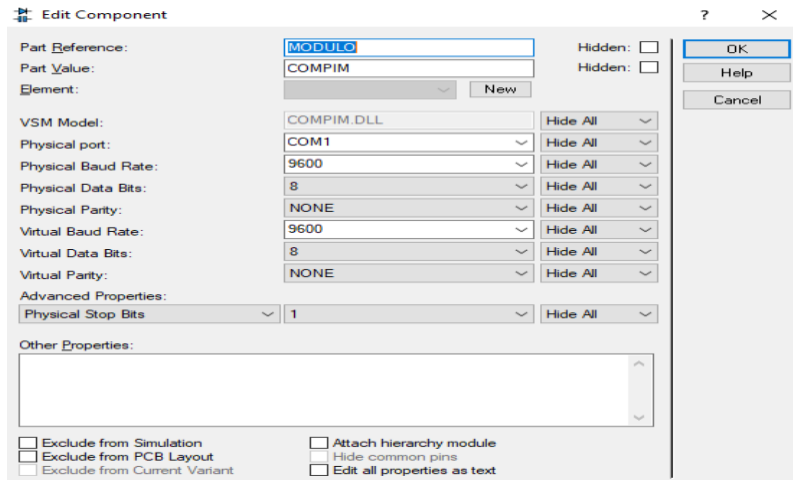


Figure VIII – Linking virtual serial ports with COMPIM in Proteus

It is essential to note that whichever port is initially created should be included in the COMPIM configuration. The program will understand that through this port, the module will receive the information, and through the next port, it will send it to the cloud (this does not need to be configured in Proteus). The same applies to the physical ESP8266 module, but in this case, the port for receiving information is configured from Arduino IDE.

2.7. Cloud and dashboard in Node-RED. - Node-RED is a tool primarily developed by IBM to connect devices, APIs, and network services. It provides a data flow editor that allows the creation of functions based on JavaScript, and its execution is built using Node.js. This means that MQTT nodes are linked via TLS with prior configuration [14].

Node-RED uses a three-stage system or components. The first is the wireless module, the second is a broker that works as an open-source middleman implementing the MQTT protocol, and its third component is real-time quality monitoring. In other words, Node-RED acts as a data receiver from the broker, and for this, flows are designed to manage and handle the received data [14].

Once the technical aspect of communication involving the use of Node-RED is understood, the design of the flow for the information measured by the sensor is carried out. A FLOW is created where an algorithm is designed in blocks, employing the following components:

- a serial input
- a debug node
- 2 functions
- 2 gauges to graphically display the measured data (dashboard)

The general diagram in Node-RED for this project is shown in Figure IX below.

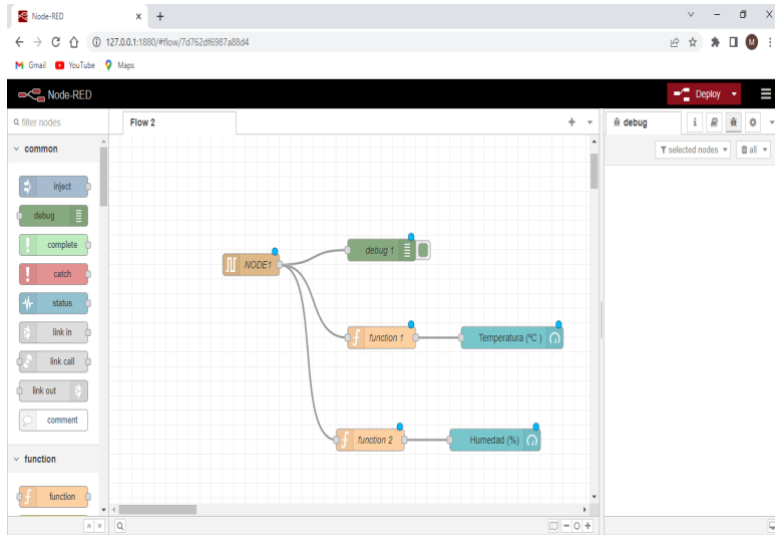


Figure IX – Node-RED Elements for Data Reception, Management, and Display

Within Node-RED, each section must be properly configured, and one of the most important configurations is the setup of the Serial-In node, which will be responsible for receiving the data measured by the sensor and sent through the serial port from the Arduino UNO to the COMPIM. It was mentioned that COM1 was the port that received the sensor data, and in this section, the virtual data receiving port is configured, as mentioned, it will be COM2, maintaining the same speed as all devices (9600 baud). As shown in Figure X.

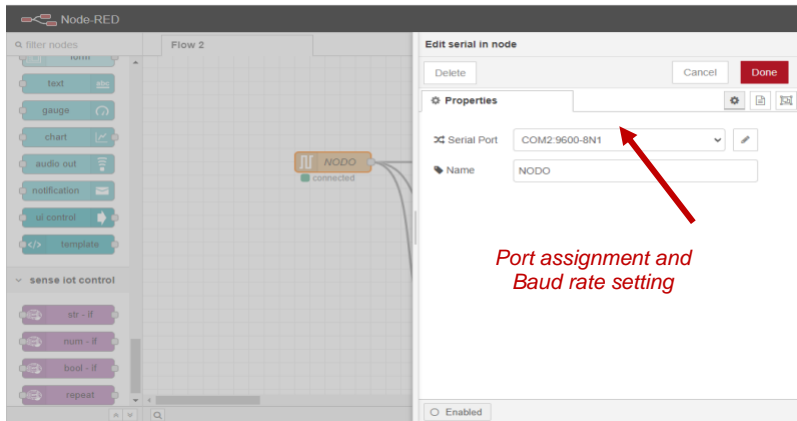


Figure X – Configuration of virtual serial port COM2

The included functions are responsible for scanning the data measured by the sensor and received by Node-RED's Serial-in, then displaying them on a dashboard or testing platform, adding scanning codes in each of the functions.

In Figures XI and XII, the functionality of the functions for each parameter is shown, scanning the values measured by the DHT11 sensor.

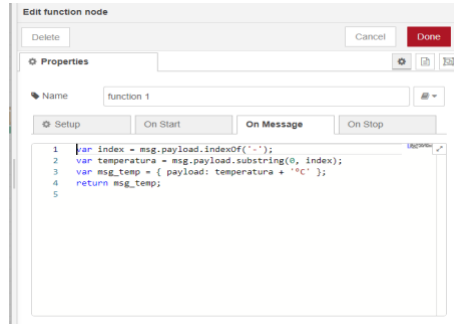


Figure XI – Scanning of measured values (Temperature)

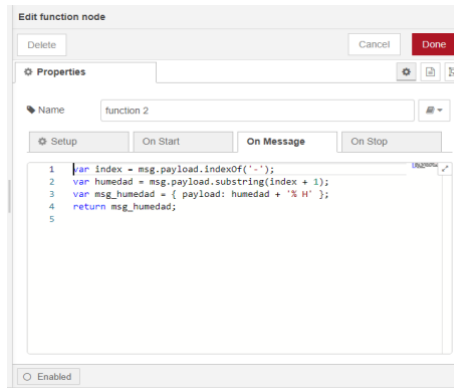


Figure XII – Scanning of measured values (Humidity)

When simulating virtual serial ports, they are created in pairs, which helps the program automatically understand that once the module receives the measurement through COM1, it immediately sends it to its simulated partner (COM2). This process fulfills the IoT objective by scanning data through ports.

2.8. Measurement and display of received information. - Once the program is up and running, the measured parameters by the sensor are taken into account. In this case, special attention is given to humidity, as it is the relevant data for analysis. The Arduino board receives the information sent by the DHT11 sensor and displays it on the device, enabling real-time adjustments and simulating an authentic field measurement. Figure XIII visually depicts this dynamic.

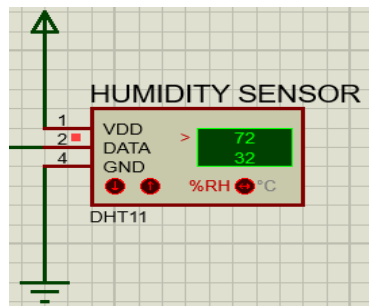


Figure XIII – Visualization of Measurement and Simulation Test Controls

For this project, parameters affecting the crops are taken into consideration. Therefore, a measurement analysis process is included, which is carried out by the UNO board. This analysis is performed because if the humidity exceeds 85%, it can cause issues in the crops [1]. Below, the overall simulation is presented with two scenarios, the first one establishing normal parameters (humidity at 82%). The DHT11 sensor measures data <1> and sends that information to the ARDUINO UNO, it is analyzed <2>, and finally, the respective message is displayed <3>. As shown in Figure XIV.

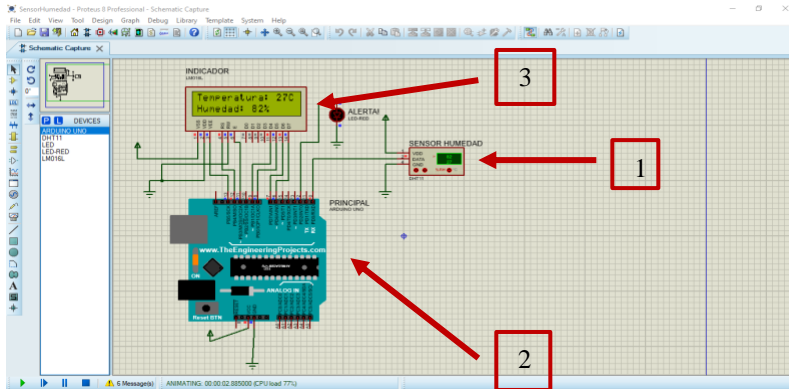


Figure XIV – Test in normal scenario

In the following scenario, it displays the measurement of data <1> with non-normal parameters (humidity above 85%) <2>. The Arduino UNO board performs the analysis again and a "High humidity percentage" message is displayed <3>. At the same time, a warning light is turned on <4> to indicate that risks may arise in cocoa crops. As shown in Figure XV.

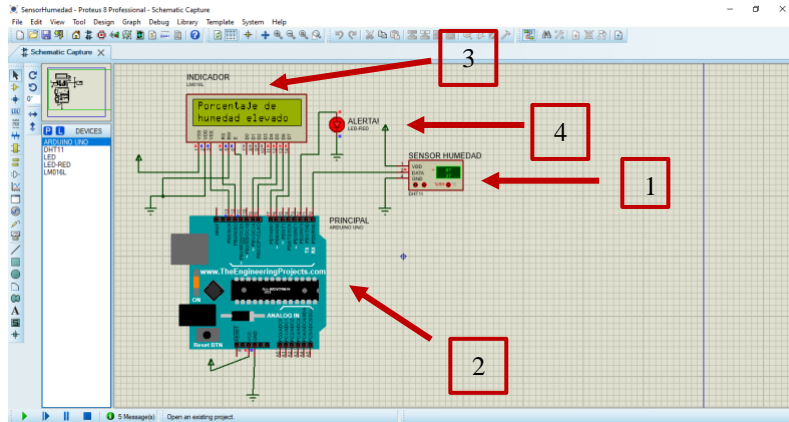


Figure XV – Test with elevated parameters

Once the measurement process is understood, the data captured by the sensor is received by the COMPIM and then uploaded to the cloud for visualization through the Node-RED dashboard. To set the entire process in motion, the operation is activated in Node-RED using the DEPLOY command, allowing the complete FLOW of the project to be displayed and testing the reception of data sent by the COMPIM. This process can be clearly seen in Figure XVI.

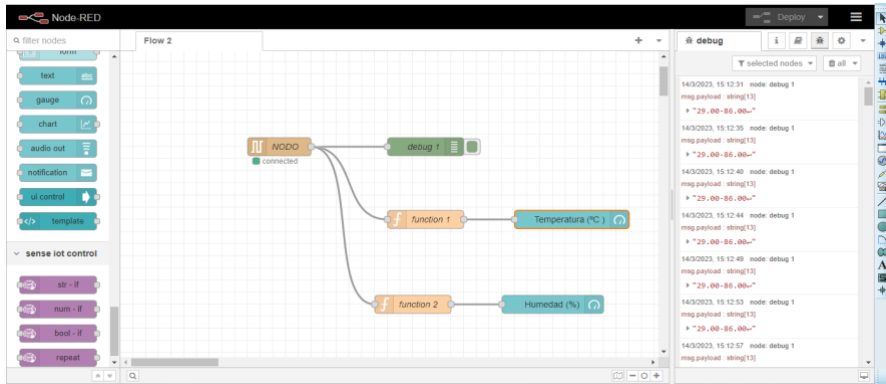


Figure XVI - Flow for Real-Time Connection with Simulation in Proteus

Through this process, IoT integration for the real-time humidity sensor node has been successfully achieved. The process initiates with a simulation in Proteus using COMPIM as the communication module and Node-RED as the logical connection tool. Thanks to this setup, data measured by the sensor is sent to the cloud and displayed on a specific platform for visualization. This process can be clearly observed in Figure XVII.

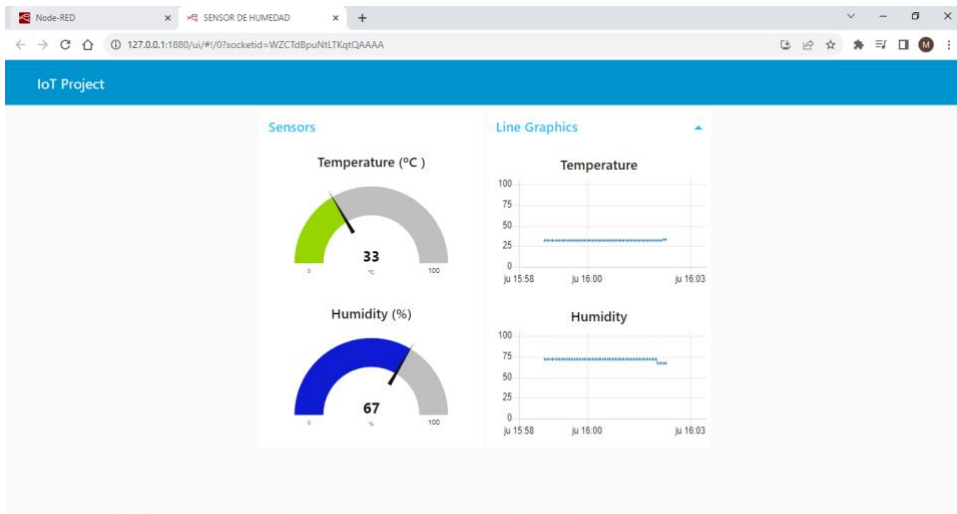


Figure XVII - Display of data measured by the DHT11 on the platform.

3. Results. - For the analysis of results, the measured parameters from a physical DHT11 sensor are considered, and the data is compared with the simulation in Proteus and web servers to gather accurate results and verify the feasibility and effectiveness of the project. Since this project is a simulation in Proteus, measurement data is manually set using the values provided by the physical DHT11 sensor. This approach allows for a realistic sampling of results and their comparison with data obtained from Google servers. Figure XVIII displays data taken from the web.



Figure XVIII - Data from the WEB

In Figure XIX, the connection of the sensor to the physical ESP8266 module is shown.

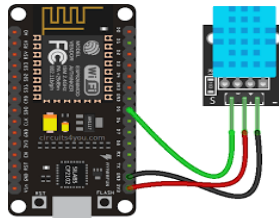


Figure XIX - Physical Connection ESP with DHT11

In order to make the aforementioned comparisons, it is necessary to configure the ESP8266 WiFi module. This configuration is done in Arduino IDE by developing the code for the module to receive the data measured by the DHT11 and then send it to the cloud for visualization. To achieve this, the intelligent platform Ubidots is included, which is a tool that enables the visualization of various variables used in the processes. It also provides the capability to make remote changes and configurations through the Ubidots web platform worldwide [15]. Figure XX shows the Ubidots IoT platform.

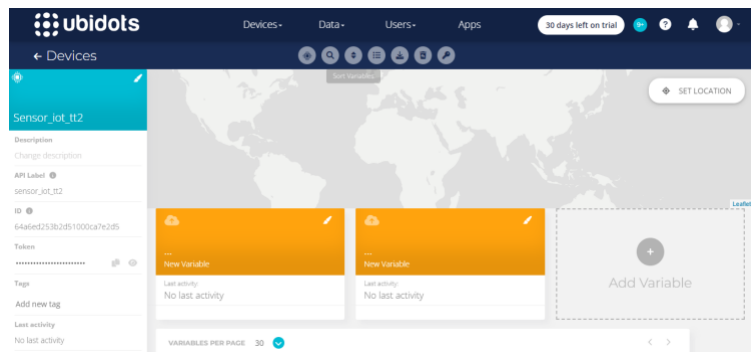


Figure XX – Ubidots Interface

The data from the DHT11 sensor is matched with the simulation in Proteus and compared with the web data mentioned. Figure XXI shows the measurement taken by the physical sensor.

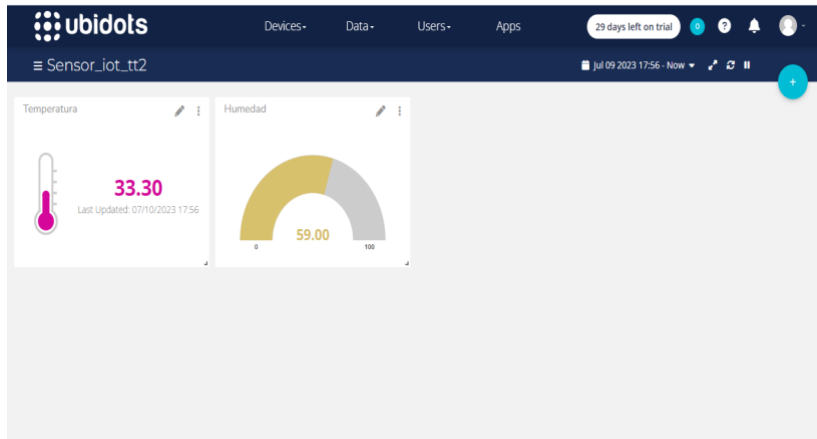


Figure XXI - Visualization of results from the physical DHT11 sensor

Ubidots also provides a historical view of the measurement results obtained by the sensor. This is especially valuable as it establishes a connection between the simulation in Proteus and the physical DHT11 sensor. Figure XXII displays historical graphs representing the chronological record of the measurements taken, enabling a retrospective analysis of data to identify patterns and trends over time. This Ubidots feature offers valuable insights for long-term data monitoring and analysis.

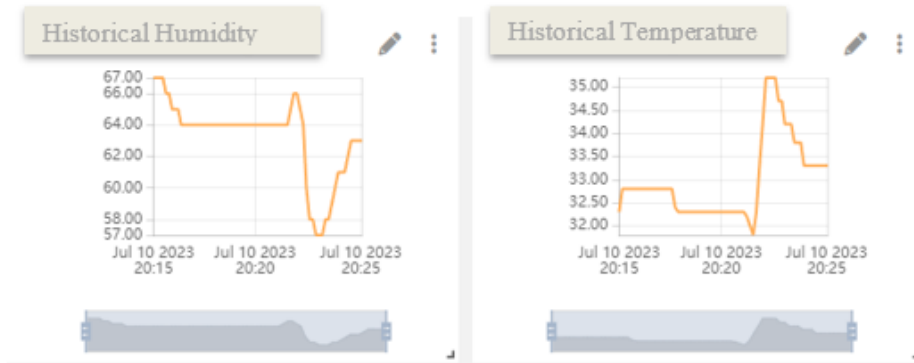


Figure XXII - View of historical results from the physical DHT11 sensor.

Based on everything mentioned, the measurements taken by the sensor are recorded in tables, as shown in Table I.

VARIABLE	MEASUREMENT
Humidity	33°C
Temperature	60%

Table I – DHT11 Sensor Values.

Next, the node's effectiveness is defined by establishing a table for the presentation of measurements over time, as shown in Table II.

PROJECT MEASUREMENT PER DAY				
Date	TEMPERATURE		HUMIDITY	
	DHT11 Sensor	Web Server	DHT11 Sensor	Web Server
4-jul-23	32°C	31°C	60%	61%
5-jul-23	32°C	31°C	61%	60%
6-jul-23	31°C	31°C	61%	60%
7-jul-23	31°C	30°C	60%	61%
8-jul-23	31°C	30°C	61%	61%
9-jul-23	33°C	31°C	60%	61%
10-jul-23	33°C	33°C	60%	61%
11-jul-23	33°C	31°C	60%	61%
	32°C	31°C	60%	61%
Reference	https://weather.com/es-US/tiempo/mensual/1/68d1fa216bf45b8ccdcde6a990584ba6603e9d0d760297b79a025c8181f81681			

Table II – Comparative measurement data and averages.

Once the sampling is established and data comparisons are completed, the calculation of humidity sensor efficiency is carried out as a means of validating the measurement process parameters. Considering equation 3, the values Vmaxc and Vminc are replaced to determine, based on humidity data, the accuracy and reliability of the sensor in obtaining data.

$$H(\%) = \left(1 - \frac{H_{max} - H_{min}}{H_{max}}\right) * 100\% \tag{3}$$

$$H(\%) = \left(1 - \frac{61 - 60}{61}\right) * 100\%$$

$$H(\%) = 98.36 \%$$

The efficiency calculation based on data (H) is determined by considering the highest data point (Hmax) and the lowest data point (Hmin) from the comparison of average humidity measurements over a specific time interval. After applying equation 3 with the data collected in Table 2, we can conclude that the measurement conducted in the project is accurate and reliable. This analysis provides us with the assurance that the humidity sensor is functioning correctly and delivering consistent results with an effectiveness exceeding 98%.

4. Discussion. - The modern world has opened a wide range of possibilities for the application of electronics in various processes, not only in technological fields but also in the integration of different branches of sciences and engineering. An example of this is the use of sensors in agriculture, as stated by the Agricultural Research Institute of the Ministry of Agriculture of Chile (INIA) in its bulletin 273. The use of technologies enhances the quality of agricultural processes [16], where applications based on telecommunications and IoT are combined to improve efficiency and productivity.

With the aim of optimizing agricultural processes, the current project has been conceived to provide benefits through the consideration of various parameters and variables that ensure proper care of

crops, especially in situations where humidity plays a crucial role in production. The project focuses on monitoring and controlling the relative humidity index, enabling informed decision-making to enhance crop performance and quality [1].

Sensors are fundamental tools that provide a wide range of measurements for data collection, analysis, and result presentation, enabling a modernization and technical improvement of crop control. Among the sensors available in the market, the DHT11 sensor stands out for its reliability and accuracy in obtaining values, efficiently adapting to different sectors. To demonstrate its usefulness, a sensor node simulation with IoT integration was carried out.

In equation 1, the analytical calculation of relative humidity is presented, a data that the sensor obtains directly and reliably.

In this simulation, two fundamental variables are considered: the percentage of relative humidity as the main parameter and temperature, as the DHT11 sensor has the capability to measure both characteristics. Its low energy consumption makes its operation straightforward.

The mentioned and visualized charts summarize the results in two different ways. On one hand, Node-RED was used as a precise tool for simulation, while Ubidots contributed intelligence that added a more realistic value to the project.

The combination of both components allowed for relating and comparing the data with Google web servers, thereby enriching the analysis and interpretation of the results.

This project provides visualizations in various graphical schemes, enabling the user to obtain a clear and comprehensive visual representation of the collected data.

These visualizations make information comprehension easier and offer a holistic view of the results, thereby contributing to more informed and effective decision-making. For the study of these variables, a thorough analysis was conducted over a specific time interval, collecting the data recorded by the sensor, as detailed in the previously mentioned Table 2. These values correspond to a daily measurement of humidity and temperature.

After conducting various measurement tests, the average of the data obtained within a specific time interval was calculated. These values represent a calculation of temperature and humidity over an 8-day range, determining an average as a reference value for precise analysis. In this calculation, there is a value corresponding to 60% relative humidity and a temperature of 32°C, which are the average measurements recorded by the DHT11 and the data provided by Google servers, also determined over an 8-day period. These values correspond to 61% humidity and a temperature of 31°C. This process was crucial for accurately determining the project's efficiency percentage, as reflected in the previously mentioned Equation 3, with an effectiveness of 98.36%. The validation of the feasibility of this project is based on these precise data, instilling confidence in its execution and success.

Taking all the above into consideration, along with insights from Oscar López's article "Calibration of Humidity Sensor" [6] and the Journal of Engineering Applications in its publication "Low-Cost Network of Humidity and Temperature Sensors" [3], the application of sensors opens up a wide range of possibilities for process improvement. This extends to areas such as industrial processes, object monitoring, and more advanced fields like aerospace, medicine, among others, and the significant impact they have within technology, robotics, and the sciences in general [17]. Furthermore, the successful development of the various components of this project demonstrates that the convergence of diverse disciplines toward a common goal can bring about significant changes in the world.

5. Conclusions. - Based on the effectiveness data obtained, it can be concluded that the humidity sensor node operates optimally and provides real measurement data. Furthermore, Node-RED, as an IoT linking tool, allows the creation of data visualization interfaces, providing users with information on changes in humidity and temperature, enabling informed decisions regarding crop care to prevent damage and losses.

The inclusion of various development software tools such as Arduino IDE and Proteus, virtual port simulators like Virtual Serial Port, and a logical and intelligent cloud communication add-on like Node-RED allows for the fulfillment of the outlined objectives in simulating the humidity sensor node for cocoa cultivation in real-time. This provides a wide field for future research projects, offering a diverse range of features provided by different sensors available in the market, along with internet communication tools. It can be applied in scientific research, experiments in various engineering branches like telecommunications, electronics, home automation, and more.

The daily weather or meteorological changes must be analyzed more rigorously to understand the potential harm they can cause to various sectors in the country. In this regard, the use of technological tools is essential to support and enhance these sectors. By employing technology, it is possible to remotely monitor weather changes, enabling more efficient and effective decision-making.

This simulation and test implementation have demonstrated an efficiency exceeding 90% when compared to data provided by internet servers or other sources showing current weather data and predictions. This result is a clear indicator of the effectiveness offered by the proposed prototype.

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Nota contribución de los autores:

1. Concepción y diseño del estudio
2. Adquisición de datos
3. Análisis de datos
4. Discusión de los resultados
5. Redacción del manuscrito
6. Aprobación de la versión final del manuscrito

HS ha contribuido en: 1, 2, 3, 4, 5 y 6.

MS ha contribuido en: 1, 2, 3, 4, 5 y 6.

DC ha contribuido en: 1, 2, 3, 4, 5 y 6.

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