Design of an IoT Platform for a Precision Agriculture (PA) in Burkina Faso

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Abstract. Producers need to have information on the agricultural parameters of their plantations without having to be on site. The objective of this work is to propose an intelligent agriculture platform or Precision Agriculture (PA) in order to collect soil humidity, air and temperature. The purpose of the PA is to contribute to food security while ensuring optimal use of resources. To do this, we offer a platform consisting of HW-390 capacitive soil humidity sensors, DHT22 air temperature and humidity sensors and microcontrollers. The HW-390 returns an analog value that gravitates around 1540 when the soil is wet and 3155 when the soil is dry. The DHT22 measures temperature and humidity with an accuracy of +/- 0.5°C and +/- 1% respectively. The power supply circuit consisting of a rechargeable battery in a maximum of 10 hours has an autonomy of 38 hours.

Keywords: Sensor, Microcontroller, Precision Agriculture (PA), ESP 32, IoT, Soil.

1 Introduction

Internet of Things (IoT) is used in almost all fields. In agriculture area, the IoT brings a considerable evolution, providing a decision support, assistance to farmers; It is about Precision Agriculture (PA). In Burkina Faso, the agriculture, livestock and hunting sectors employ more than 63% of the population (RGPH 2019)[1]. Unfortunately, in addition to climatic hazards, farmers are faced with:

- The data inaccessibility from fields remotel. The remote access to field information could help farmers to avoid frequent travel. The information such as the soil's humidity rate could also enable trigger a sprinkler system for example;
- The lack of database to help for decision-making: Collecting and processing field data could enable farmers to take better decisions;
- Misuse of water resources;

[1] Recensement Général de la Population et de l'Habitation

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- The high cost of labor: The installation of a watering device on the basis of the data collected could contribute to reduce the labor.

To allow farmers to access data from their fields remotely, we have set ourselves the following overall objective: Set up an energy-autonomous AP platform for data collection. To do this, a number of actions have been identified as follows:

- Collecting soil moisture, temperature and air humidity;
- The data processing collected to derive information from it;
- Access to various information provided by the remote controller;
- The energy supply management of the whole device.

This paper is organized in four (03) sections. The first section is entitled ”state of the art” in which we recall the communication technologies used in smart agriculture or precision agriculture (PA) as well as similar works. In the second section entitled “Proposed approach”, we discuss the different communication technologies and the threats related to PA in order to propose an architecture to our system. We also present our prototype in this section. The results of our work as well as their interpretations are the subject of the third section. Finally, our document ends with a conclusion and some perspectives.

2 State of the art

In this section, we will on the one hand make a reminder of some technologies used for the communication between the nodes of sensors and on the other hand present similar works.

2.1 Communication networks between sensor nodes

Today, there is a wide choice in terms of wireless communication technologies for setting up an IoT system. Depending on the different specifications and constraints related to the system, in this section, we are listing the most appropriate technologies taking into account 4 main parameters which are:

- ➢ The range
- ➢ The data transmission rate
- ➢ The energy consumption
- ➢ The deployment cost

There are two major types of wireless communication networks which are widely used in IoT platforms. Short-range networks including Wifi technology and LPWAN (Low Power Wide Area Networks) networks including SigFox and LoRaWAN (Long Range Radio Wide Area Network) technologies.

Cellular networks can also be used by IoT systems. However, they have the disadvantage of being greedy in energy consumption and also the hardware is high costly. It is also possible to access data from local sensors directly. This solution is safer in terms of data availability and security. However, it is not suitable for our project since it does not allow remote access to data.

Table 1: Summary of the different technologies

	SigFox	**LoRaWAN**	**Wifi**		
			802.11b	802.11g	802.11
maximum range	10 km in urban 15 km in Rural	5 km in urbain 15 km in rural	50 m interior 200 m outside	20 m interior 50 m outside	70 m interior 250 m outside
Debit	100 bps	22 Ks/s	11 Mbps	54 Mbps	150 Mbps
Energy consumption	low		High		
deployment cost	High		low		

2.2 Similar works

There are many works done on precision agriculture. In this section, we will come back to some of these works that seems relevant to our project.

- **Design Architecture of Autonomous Precision Farming System [1]:** This paper describes the design and development of an Autonomous Precision Farming System (APFS) for agriculture automation. It is a low power user friendly system which helps the farmers to plan irrigation and fertilization based on environmental and soil conditions. The system can intelligently operate pumps / valves based on the data available from the field and the preloaded programs available in the controller. APFS monitors and maintains the various farming parameters like soil moisture, pH level, atmospheric temperature, humidity, fertilizer concentration etc. and appraises the information to farmers. APFS features Wireless data acquisition through wireless motes. The graphical TFT touch screen provides responsive user interface. The farmers can configure the device to getting alerts of critical field parameters or hazardous conditions. These alerts can be conveyed to the farmer in the form of preprogrammed text Messages to his mobile phone through SMS. The system also incorporates mechanism for controlling the agricultural field equipment from a remote location through DTMF technique using mobile phones.

- **Internet of Things (IoT) for Precision Agricultur Application [2]:** In this paper, the authors propose an application of cloud based IoT in the agriculture domain as showed in 1. The fundamental idea is to sense all the required parameters from the agriculture field and to take required decision to control the actuator. These agriculture parameters are Soil Moisture, Temperature & Relative Humidity (DHT11) around plant, Light intensity. Based on the reading sensed by the sensor, suitable action is taken i.e. irrigation valve is actuated based on soil moisture readings, valve for fogger (for spraying water droplet) is actuated based on the Relative humidity(RH) readings etc. This paper proposed also the development of the sensor node capable of measuring all these parameters and creating the actuation signal for all the actuators. On top of that sensor nodes are also capable of sending this data to cloud. An Android application is also developed in order to access all these agricultural parameters.

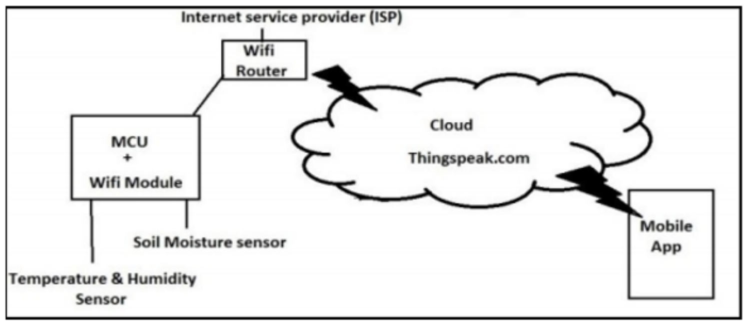

Fig. 1. Diagram of the architecture proposed by[2]

As mentioned earlier, the mobile application was created to visualize the data in the mobile phone. Data from Thingspeak cloud was exported using API key and stream status URL is used for each field of particular channel. All data are exported to mobile app as shown in figure 2.

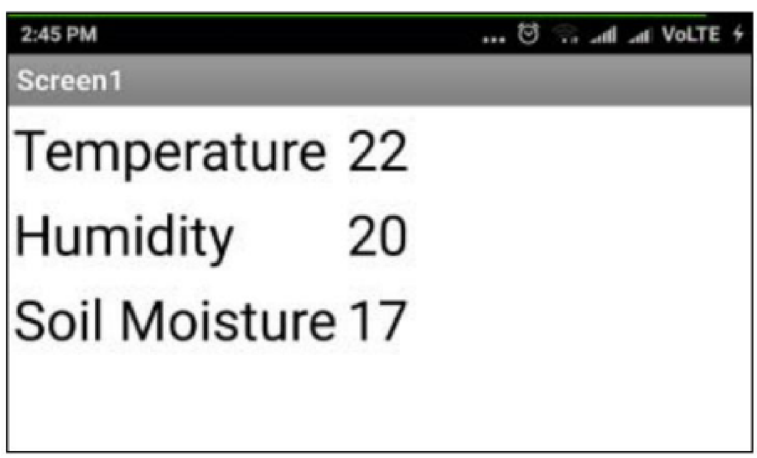

Fig. 2. mobile app proposed by [2]

- **Precision Agriculture System Using Verilog Hardware Description Language to Design an ASIC [3]:** This paper explains how traditional agriculture in India can be replaced with smart and precision agriculture by controlling different parameters using programmed hardware through

Verilog hardware description language with available sensor network data to develop an ASIC. The different parameters which are responsible for growth of plant are controlled in such way the production and the growth of plant can be improved rapidly to compare with traditional agriculture. The authors use precision agriculture organic farming to overcome disease cause by inorganic farming. The Precision Agriculture System is implemented based on ASIC using Verilog Hardware Description Language (VHDL). The system monitors water supply, pH value, nutrient ratio, temperature, humidity and light intensity. The processor is programmed to control the hardware based on sensor data. For outdoor farming, it is possible to monitor all the parameters mentioned above, but only control water supply, nutrient levels and humidity. On the other hand, for indoor breeding, it is possible to monitor and control all the parameters mentioned above.

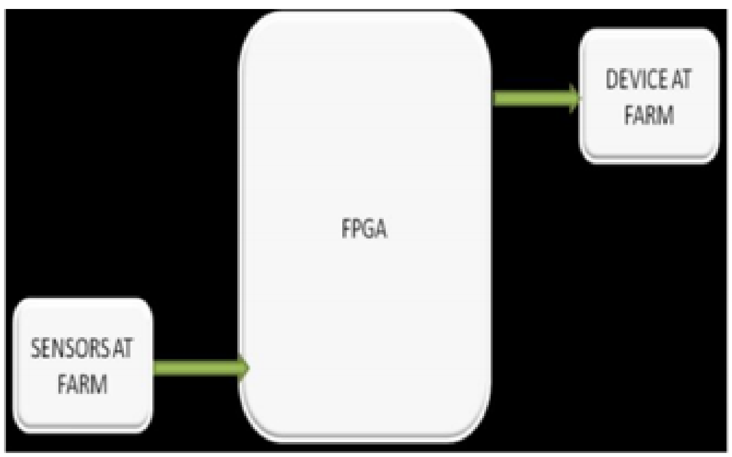

Fig. 3. Diagram of the architecture proposed by [3]

Figure 3 shows how the system works. The sensors collect the data and then transfer it to the processor. After having received the data, the processor processes them and possibly triggers the actuators according to the algorithm.

➢ **Design and implementation of a connected field for better crop management [4]:** this work consisted of collecting soil data such as PH, temperature, relative humidity, soil humidity , light. This data is accessible from a web application. It has also integrated an automatic arrogate system.

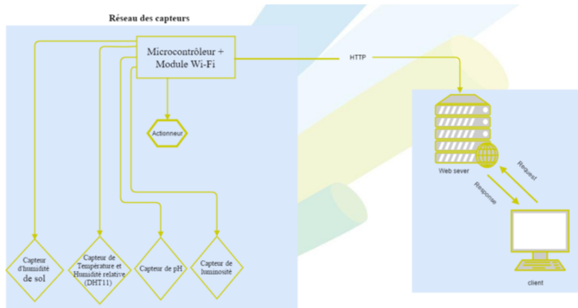

Fig. 4. Diagram of the architecture proposed by [4]

Figure 4 shows the architecture of the system. The sensors and the shareholders are connected to a microcontroller which integrates a wifi module and forms a network. The Wifi module sends data to the web server through the HTTP port. The user accesses the data by connecting to the server using a computer or smartphone.

➢ **Design and development of a system for integrated aquaculture based on the Internet of Things [5]:** The approach proposed in this document aims at reconciling aquaculture and agriculture in a system where they are interoperable. The agriculture part consisted of collecting the moisture content of the soil. When the soil is dry, the system allows watering from the water used for aquaculture if it is no longer conducive to the proper development of the fish. A system monitoring application was developed using APIs from the Adafruit and Firebase IoT platforms.

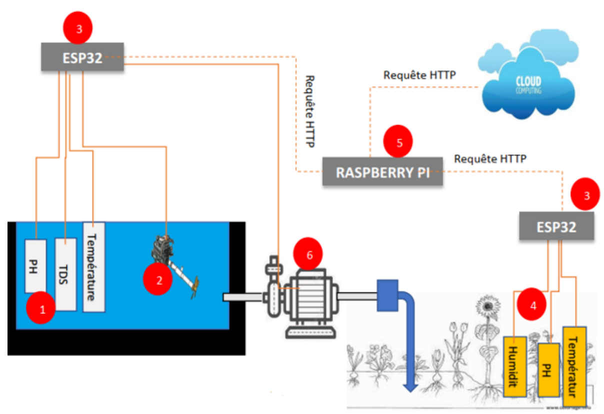

Fig. 5. Diagram of the architecture proposed by[5]

➢ **IoT applied in Agriculture [6]:** This paper proposes to create a supervision system based on an IoT platform for monitoring the various of field data (temperature, soil humidity, air humidity and luminosity) collected from the sensors. The Thingspeaks IoT platform is used as both a display interface and a database.

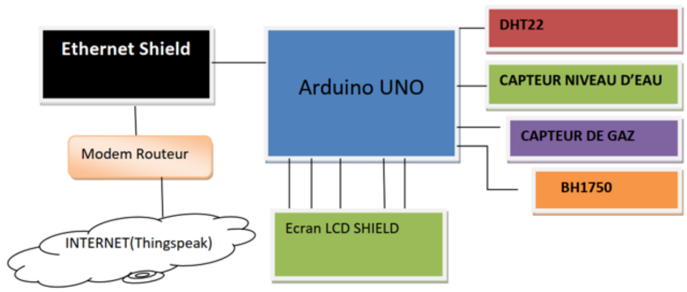

Fig. 6. Diagram of the architecture proposed by [6]

Figure 6 presents an architecture consisting of three parts. The first part consists of sensors that collect data from physical phenomena (temperature, humidity, pressure, wind speed and the presence of rain). The second part consisting of a microcontroller allows data processing. Finally, the last part is the unit that allows data transmission (Ethernet Shield).

- ➢ **Low cost IoT solutions for agricultures fish farmers in Africa:a case study from Burkina Faso [7]:** The authors of this article share their experience on the deployment of sensors. These deployed sensors measure: -PH, dissolved oxygen and temperature in the water of a claria hatchery (poison species) to monitor the mortality of alevins ; -Soil moisture in banana and papaya fields to optimize the watering of aquaculture ponds with rich water; -Meteorological parameters to determine the correlation between meteorological parameters and field production.
  The data collected are sent on a Cloud platform or are sent by SMS via a gateway equipped with LoRa module and a 3G modem.
- ➢ **Low cost IoT solutions for fish farmers in Africa[8]:** The authors of this work deployed a low-cost, connected water monitoring system measuring temperature, PH and dissolved oxygen in a fish farm in Ghana. This work highlighted some recurring water quality problems and proposed solutions.

2.3 Similar works limitations

In this section, we compare similar works that was relevant for our study in the table 2. The following criteria used for comparison are consired:

- **Sensors type:** The choice of sensors is important for a precision farming platform. Some moisture sensors cannot last long in the ground without deteriorating. Also the accuracy of the sensors is an element to take into account because some crops are sensitive to temperature;

- **Microcontroller type:** Its choice must take into account certain parameters such as connectivity (Wifi, bluetooth, Internet..), energy consumption, security and data processing power;
- **Date communication between different nodes:** The choice of communication technology between the different nodes must be done carefully by considering the energy consumption, the distance between the different nodes and the size of the data;
- **The availability of remote data:** A PA plant should allow the farmer to have remote access to the field data.
- **Power and autonomy:** For an AP platform that will be deployed on site that does not necessarily house electrical installations, it is essential to provide an autonomous power supply system.

Table 2: Summary of similar works.

Article	**humidity sensor**	**Temperature sensor**	**Microcontroller**	**Communication between nodes**	**Availability of remote data**	**Autonomous power supply**
Rajani et al [1]	Unspecified	Unspecified	Unspecified	Zigbee	GSM	Not taken into account
Ghodinde Et Dholu [2]	Resistive sensor	DHT 11	ESP8266	Not taken into account	Internet	Not taken into account
Patidar et al [3]	Unspecified	Unspecified	FPGA (Prototype)	Not taken into account	Not taken into account	Not taken into account
Coulibaly et al [6]	Resistive sensor	DHT 22	Arduino Uno	Not taken into account	Internet	Not taken into account
SALL et al [4]	Resistive sensor	DHT 11	Arduino Uno	Not taken into account	Internet	Not taken into account
BELEM et al [5]	Resistive sensor	DHT 11	ESP 32	Not taken into account	Internet	Not taken into account
Téeg-wendé ZOUGMORE et al [7]	Resistive sensor	Not taken into account	Arduino Pro Mini 32	LoRa	Internet et GSM	autonomous
Charlotte DUPOND et al [8]	Not taken into account	Not taken into account 11	Arduino Pro Mini 32	LoRa	Internet and GSM	autonomous

The solutions proposed in [2], [4], [5] and [6] have some limitations. The humidity sensors used is a resistive type[2]. By opposition, the capacitive humidity sensors which is used in our platform, the resistive sensors are not suitable for staying underground for a long time due to the corrosion.

Also the temperature sensor used in most of the similar works is the DHT 11 which has an accuracy of +/- 2 degree C while the DHT22 used in our platform has an accuracy of +/- 0.5 degree C. Some crops, especially in greenhouses, are sensitive to temperature. It is therefore important to use sensors that have good accuracy.

In addition, the proposed solutions in similar works have not integrated energy management. The question of autonomy is a key factor in an AP platform.
Certain of the similar works propose a remote visualization of the collected data based on the Internet. For a platform which is deployed in rural areas, the Internet access may be an issue. It should be noted that these solutions have not been deployed.

One of the limitation of similar works is the usage of the Arduino microcontrollers used in [6] and [4] which are expensive and are high power consuming. Adding the fact, they do not integrate Wifi. They are not suitable for smart farming.

3 Proposed solution and implementation

3.1 Architecture

Our approach consists in designing a data monitoring prototype (temperature, soil humidity rate and air humidity rate) of a field. In view of the advantages and disadvantages of the various technologies listed above, we have come to the following proposal:

- Design several nodes consisting of sensors and a microcontroller;
- Usage of the wifi technology for local communication between the nodes and the processing unit which includes a gateway to the outside;
- Usage of an external gateway capable of sending and transferring data in the form of SMS using the GSM network.

To achieve the defined objectives, the microcontrollers connected each to soil moisture sensors and air temperature and humidity sensors. The data collected by these microcontrollers is centralized towards another microcontroller which also constitutes the gateway to the exterior. The gateway allows data to be sent to a telephone number in the form of an SMS.

[2] A resistance force sensor, resistive force sensor (in English: Force-sensing resistor or FSR) is an electronic force sensor whose resistance varies according to the pressure applied to it

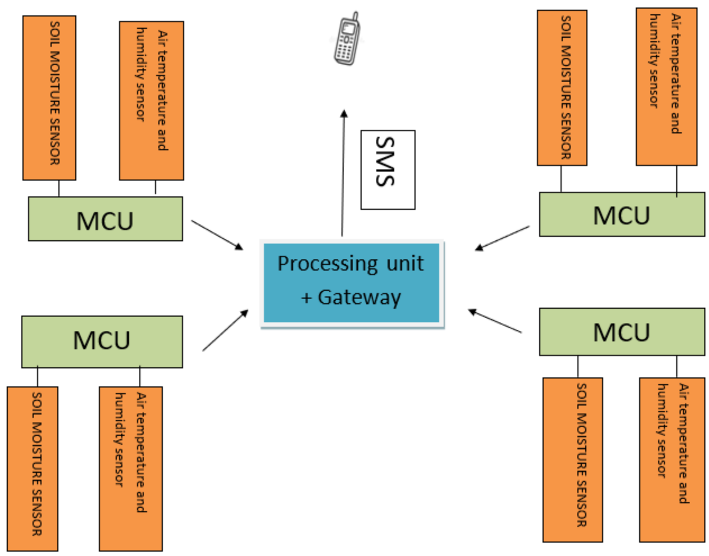

Fig. 7. Architecture of our smart farming platform

3.2 Circuit Power

The energy is very important aspaect in the IoT platform design. Our platform should be deployed immediately and a solar power system would be more suitable. We offer a power supply circuit consisting of:

- solar panels;
- Charge regulators: They allow the battery to be properly charged;
- Batteries;
- Voltage regulators: They are used to deliver the voltage necessary for the proper functioning of microcontrollers.

Figure 8 shows how the above elements are assembled to form the circuit.

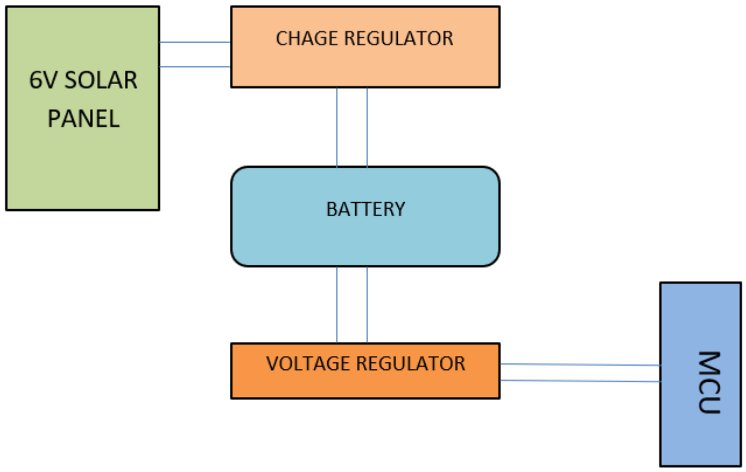

Fig. 8. Power circuit of the proposed IoT platform

3.3 The sensor node prototype

The node consists mainly in a DTH22 air temperature, an humidity sensor, an HW-390 soil humidity sensor, a microcontroller, a 3.7V lithium battery, and a 6 volt solar panel.

The outputs of the HW-390 and DHT22 sensors are respectively connected to pin 32 and 16 of the ESP32 microcontroller. The sensor-microcontroller assembly is powered by the battery. The ESP 32 operates at a voltage between 2.6 and 3.6 V. A 3000 mAh and 3.7 V Lithium battery and 6 V panels are suitable for powering the circuit autonomously. A TP4056 charge regulator module is placed between the solar panel and the battery so that it is not charged beyond 4.2V. A voltage regulator should also be integrated between the battery and the ESP 32 microcontroller. The role of this regulator is to lower the voltage supplied by the battery so that it complies with the nominal voltage of the ESP32, i.e. 3.3V. Unfortunately, we were unable to acquire the voltage regulator that is suitable for our assembly. To overcome this issue, we have limited battery charging to a maximum voltage of 3.64 V in order to protect our microcontroller.

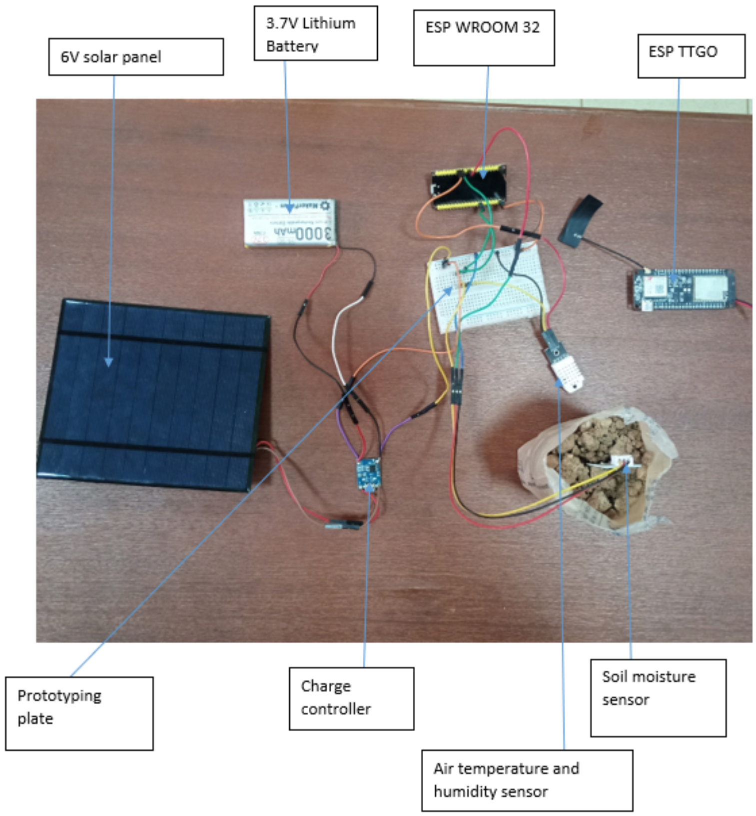

Fig. 9. Mounting a sensor node

3.3.1 Humidity sensor choice

We find two main types of soil moisture sensors on the market in 2021: Resistive sensors and capacitive sensors.

Resistive sensors are not suitable for staying underground for a long time due to their corrosion, so we will choose capacitive sensors if they show better endurance over time.

Capacitive sensors measure a range of frequencies. This value is obtained by measuring the dielectric permittivity of the ground (ε). Concretely, an electromagnetic field is deployed around these sensors. The constituents of the soil (mineral and organic particles, water, air, etc.) will more or less disturb this electromagnetic field. To have precise measurements, it is necessary to carry out a calibration with the ground coming from the place where the sensors will be implanted.
It is made of a material resistant to corrosion, which gives it a long life .

[9] shows that the FDR sensor which is a capacitive sensor is suitable for determining dry or wet ground and recommends using it in a long-term measurement unlike the resistive sensor. We

Fig. 10. HW-390 Capacitive Soil Moisture Sensor

chose a HW-390 capacitive sensor as shown in figure 10.

3.3.2 Weather sensor selection

The advantage of using a metrological sensor (air temperature and humidity) is to be able to:

- Looking for correlations between air temperature and humidity and humidity at plant root level. This would allow us to look for possible relationships between certain natural phenomena (evaporation, dew, etc.) and soil humidity. We can assume that there will be an impact between the dryness of the soil and that of the surrounding air;
- Detection of the presence of rain in the field: For decision-making on watering, this factor will be of some importance.

In order to facilitate our IoT system implementation, we have instead opted for a digital sensor.

There is a wide variety of digital sensors such as the BMP180, DHT11, BME280 and DHT22... These digital sensors have interesting characteristics for our project. However, our choice fell on the DHT22 sensor which makes it possible to acquire the temperature with an accuracy of +/- 0.5°C and the ambient humidity in a digital way.

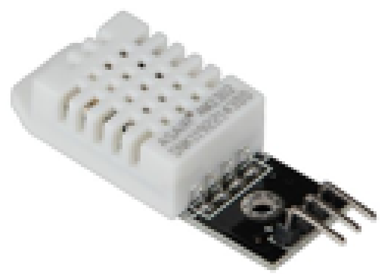

Fig. 11. DHT 22 Temperature Sensor

3.3.3 Microcontroller choice

During our research, we identified two main families of microcontrollers: Arduino and ESP. Both of these builders have the documentation, community, and accessibility necessary for faster development of our application. In both cases, there are a multitude of libraries that facilitate the use of the many existing sensors.

The table below summarizes the characteristics of the most common models, and of equivalent prices found on the two platforms.

Table 3: Arduino-ESP32 Comparison

	ARDUINO UNO	**ESPWROOM32**
Operating voltage	5V	3,3V
Normal current consumption	35mA	20 mA – 240 mA
Current consumption in standby mode	No sleep mode	5 µA
Non-volatile memory	32 kB	4 MB
Development environment	Arduino	Arduino ; C ; micropython, circuit-python ; lua ; JavaScript
RAM	2 kB	512 kB
Processing speed	816 MHZ	2 × 240 MHZ (double hearts)
Connectivity	None	Wifi up to 150 Mbps; Bluetooth V 4.2 BLE
Cost	22-38.50$	About 11$

For the implementation of the IoT platform, we chose the ESP32-WROOM-32 microcontroller for the simple reason that the ESP-WROOM-32 Wifi Bluetooth ESP32 Development Board is a powerful generic Wifi-BT-BLE MCU module that targets a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, such as voice encoding, music streaming and MP3 decoding.

Additionally, the standby current of the ESP32 chip is around 5μA, making it suitable for battery-powered applications. Similarly, the presence of Bluetooth technologies but especially Wifi makes it a good candidate for our system.

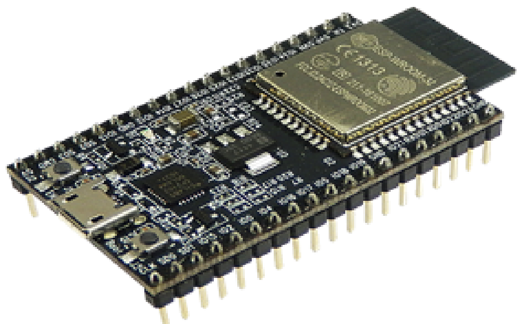

Fig. 12. ESP-WROOM-32

3.3.4 The Gateway choice

As the ESP ecosystem offers microcontrollers with GSM connectivity, we were interested in a particular model: the TTGO T-CALL ESP.

The TTGO T-CALL ESP microcontroller is a new ESP32 development board associated with a module SIM800L GSM/GPRS. The new board combines ESP32 WiFi and Bluetooth with the SIMCom SIM800L GPRS and also relies on a USB-C port for power and programming. It can also be autonomous thanks to an integrated battery charger supporting batteries up to 500 mA.
In addition to Wi-Fi and Bluetooth, you can communicate bidirectionally with this card by inserting a nano SIM:

- ➢ by SMS ;
- ➢ By phone calls ;
- ➢ Or by Internet if the 2G network allows it.

It is ideal for IoT projects that do not have access to a nearby router.

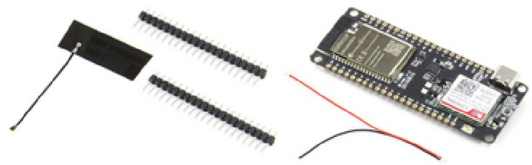

Fig. 13. TTGO T-CALL ESP

3.3.5 Battery selection

The ESP32 can be powered with 5V via USB, as well as 3.3V from its pins. A battery with a slightly higher voltage is able to power it. We therefore chose the 3.7v 3000 mAh rechargeable Lithium batteries. The maximum working current of this battery is only about 1.5A. This type of battery is suitable for powering ESP32s.

Fig. 14. Lithium battery

3.3.6 Solar panel

The Lithium battery can be recharged using a solar panel.
To correctly recharge our battery, we will need a solar panel which nominal voltage is at least or equal to 3.7V, ideally 10% to 20% higher. A 6V panel can largely meet our needs.

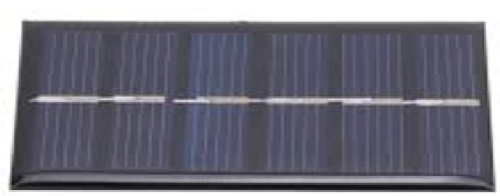

Fig. 15. Solar panel used by IoT-platform.

3.3.7 TP4056 charge controller

You need a charge regulator between the solar panel and the battery. It regulates the battery charge by limiting the voltage to avoid overcharging. It also allows to limit the discharge of the battery to a minimum voltage.
The TP4056 charge regulator limits the battery charge to 4.2 V , which corresponds to the charging voltage of our battery.

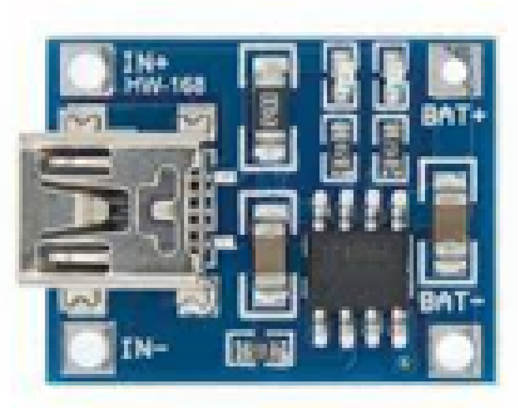

Fig. 16. TP4056

3.3.8 Arduino IDE and Arduino programming language

The Arduino software is an open source and free Integrated Development Environment (IDE). It makes it easy to write code and upload it to the development board. This software can be used with any microcontroller compatible with the Arduino board. It works on Windows, Mac OS X and Linux. On the Arduino IDE the languages are written in C, micro-python and C++ (or arduino language).

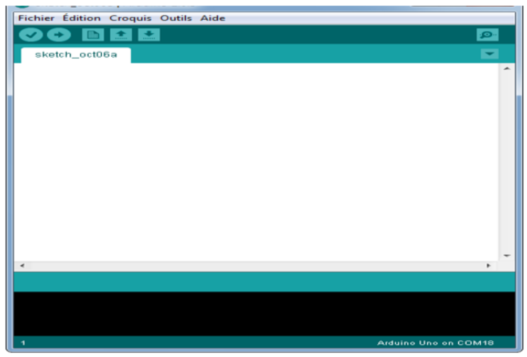

Fig. 17. IDE Arduino

4 Results and analysis

In this section, we present and discuss the results of our work.

4.1 Soil moisture

The figures 18 and 19 represent respectively the raw values and the percentage values of our soil moisture sensor on a soil sample. Experimentation shows that our temperature, air humidity and soil moisture sensors work well.

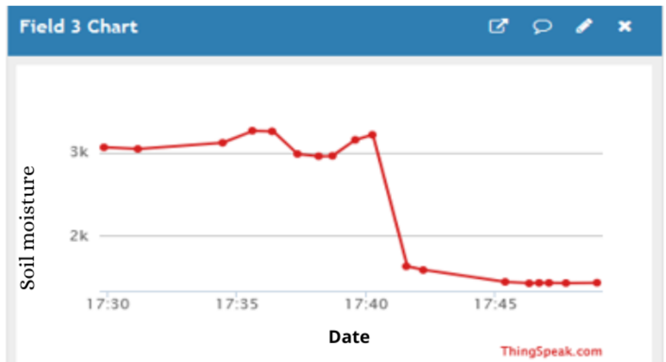

Fig. 18. Raw Soil Moisture Values

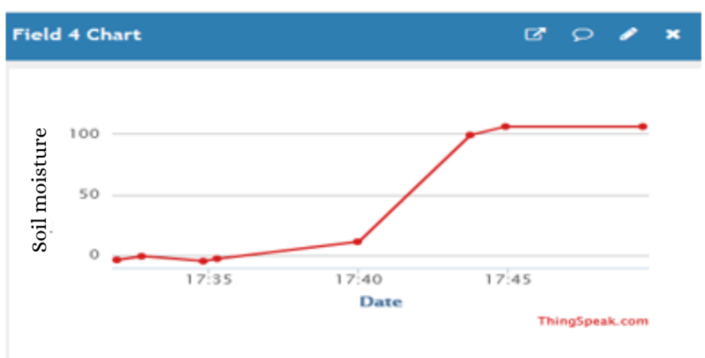

Fig. 19. Soil moisture percentage values

Indeed, the soil moisture sensor returns an analog value that gravitates around 1540 when the soil is wet and 3155 when the soil is dry (refer to figure 18). This analog data does not give an easy reading of soil moisture level.In order to have a humidity rate in percentage, we mapped the values between 1540 and 3155. The values 1540 and 3155 are considered as reference values respectively for a very humid soil and a dry soil. It should be emphasized that these reference values are trends. They may vary slightly depending on the type of soil. Thus, we will have values between 0% (if the soil is dry) and 100% (if the soil is very humid) in order to have a clearer idea of the soil moisture level (figure 19).
However, the sensor we use does not have a stable calibration. This explains a humidity level slightly above 100 or below 0 at times. This level of sensor accuracy is sufficient for our platform.
Calibrated sensors are essential to ensure accurate and reliable measurement results. Ground texture, wear and aging of sensors can reduce accuracy.

4.2 Air temperature and humidity

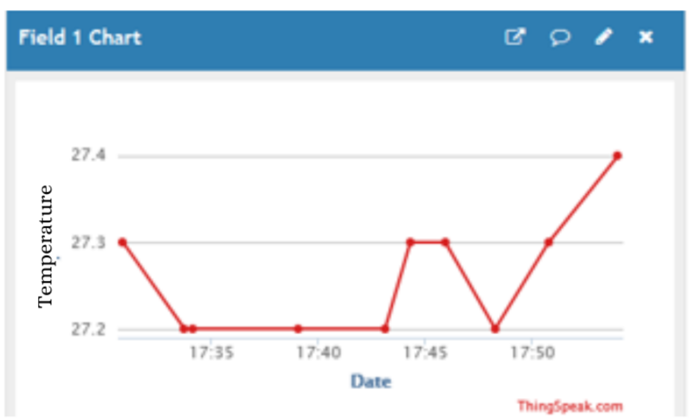

Fig. 20. Temperature values

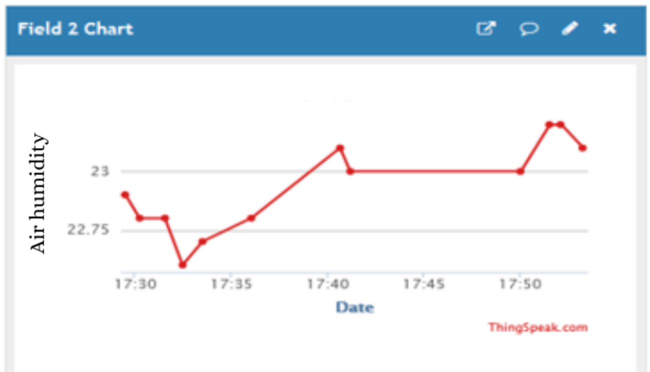

Fig. 21. Air humidity values

On the Figure 20 and 21 we can respectively observe the variations of the ambient temperature and the rate of humidity of the air.
It is observed that the temperature remains within a range of 27.2 to 27.5 degree C throughout the measurement. The variation is in the order of +/- 0.5 degree C. So we have a good sensor. The air humidity rate is between 22 and 23 %.

4.3 Battery charging

We have carried out tests for verifying the charging time of the batteries using the solar panels. The solar panels used in our IoT-platform are 3 V and 6 V panels.
Under the same conditions (partially cloudy sky) the 6V panel delivers 127 mA, the 2 3v solar panels connected in parallel deliver 80 mA, and each 3V panel delivers 38 mA.
The table below shows the battery charging time according to the capacity of the panels when the sky is partly cloudy based on the formula 1.

$$Full\ charge\ time\ (hour) = \frac{Battery\ capacity(Ampere\ hour)}{Current\ delivered\ by\ the\ panel\ (Ampere)} \tag{1}$$

We use 3000 mAh batteries with a maximum charge of 4.2V. The battery cannot be discharged below 2.6V because from this voltage it can no longer operate the ESP32. The passage of the voltage from 4.2 V to 2.6 V corresponds to a discharge of approximately 40%. So we need 40% of the charging time to bring the battery back up.

Table 4: Charging time according to panel capacity

Panels	**Current delivered**	**Full charge time from 0v**	**Charging time from 2.6V**
Panels of 6V	127 mA	23h	10h
two 3V panels connected in parallel	80 mA	37,5h	15h
Panels de 3V	38 mA	79h	31h

The obtained values in the table 4 are calculated in the worst case because in practice the system does not consume enough energy for the battery to reach a discharge level of 2.6V.
With regard to the current delivered by the different panels and the autonomy of our system, a 6V panel or two 3V panels mounted in series allow the battery to be charged properly during the day.

4.4 ESP32 power consumption

We conducted several tests to assess the autonomy of our system. Not having a suitable voltage regulator to connect our battery to the microcontroller, we limited the charge to 3.64 V (voltage supported by the ESP32) for the tests. The table **??** presents the conditions under which the tests were carried out as well as the results.

In test 3 We try to optimize the energy consumption compared to test 2. The circuit is improved so that the sensors are powered by pins of the ESP32. The sensors only consume energy when you want to retrieve data. It has been found that with this circuit model, the values returned by the sensors immediately upon awakening of the ESP 32 are not exact. Assuming this is due to the initialization time of the sensors when powered, we added a delay (2 seconds) after the ESP32 boots up before retrieving the data. This solved the problem. Unfortunately, the delay we are forced to add contributes to increase energy consumption since the ESP stays awake longer. Also operation in wifi mode constrains more energy (theoretical 80 to 180 mA). WiFi detection and sending data to the server takes about 10 seconds.

In addition, in deepsleep mode, the ESP32 turns off the CPU and the corresponding crystal oscillator. An internal oscillator ensures that time continues to run. However, this internal oscillator is very inaccurate and temperature dependent, so in permanent deep-sleep mode a deviation of 20% and more can quickly occur. This means that after a few days the watch is no longer correct. In addition, the time is reset to 0 during a battery change or a reset. This is quite problematic for long-term battery operation. Also, we believe that the autonomy of our circuit can always be improved. In reality, the ESP32 incorporates an AMS1117 regulator for power supply via USB. This regulator contributes to the consumption of the energy in our circuit although it is useless because our ESP is fed via its pins.

It appears from the various tests that our system has an autonomy of 38 hours under the fol-

Table 5: Autonomy tests

	Test 1	Test 2	Test 3
Initial battery voltage	3,64 V	3,64 V	3,64 V
Battery end voltage	2,8 V	2,8 V	2,8 V
Operating Condition	• Data is continuously sent to a server • The battery directly powers the microcontroller and sensors	• The esp is in deep-sleep mode and wakes up every 1 hour to send data to a server • The battery directly powers the microcontroller and sensors	• The esp is in deep-sleep mode and wakes up every 1 hour to send the data to a server • The battery directly powers the microcontroller • The sensors are powered by the pins of the microcontroller
Autonomy	20h	29 h	38h

lowing conditions:

- The ESP32 is in deepsleep mode and wakes up every 1 hour to send data to a server;
- The battery directly powers the microcontroller;
- The sensors are powered by the microcontroller pins.

This means that if during the day the panel manages to charge our battery to at least 3.64 V, our microcontroller will be able to operate all night. We also note that for the 3 tests the final charge of each of the batteries is 2.8. This means that from this voltage, the battery is no longer able to operate the ESP32. We can conclude that the result obtained in test 3 is acceptable.

5 Conclusion and perspectives

Our work was carried out as part of the search for a solution for monitoring soil moisture, temperature and air humidity of a field. At the end of our research, we were able to propose a system composed of several sensor nodes which collect data and then transfer them to a processing unit. The processing unit incorporates a gateway to the exterior which allows information to be sent in the form of SMS to the user via the GSM network. We also proposed a power supply circuit allowing our system to be autonomous.

This project has enabled us to achieve satisfactory results. The HW-390 capacitive soil humidity sensors and the DHT22 air temperature and humidity sensors measure with interesting precision. A 6V solar panel can recharge the 3.7V Lithium battery in maximum 10 hours powers the system with an autonomy of 38 hours.

However, we must continue to work on certain points in order to improve our system. These include in particular:

- Improving the autonomy of our system by replacing the ESP-WROOM-32 with low-power microcontrollers such as ESP ECO POWER or ESP-12F; or by using a microcontroller that integrates ZigBee which is a low consumption technology compared to Wi-Fi;
- Designing a monitoring web application to allow the user to regularly follow the parameters of the field from a smartphone or a computer;

In order to allow a better management of the water intended for the watering of the plants, we have in perspective the integration of an automatic watering system to our platform.

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