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AN INTELLIGENT APPROACH TO MONITORING AN AGRICULTURAL GREENHOUSE VIA A 4G NETWORK IN THE REPUBLIC OF CONGO

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Abstract

This article presents a contribution to management approaches aimed at modernizing the agricultural sector in Republic of Congo by setting up an automatic control and regulation system for an agricultural greenhouse. This system will enable farmers, via a mobile phone

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network, to effectively control their greenhouses in order to ensure excellent quantitative and qualitative production on the one hand, and to reduce operating costs via automatic control on the other. In order to achieve this, the first step was to set up a network of intelligent sensors located at certain points in the greenhouse, enabling the state of the climatic parameters in the greenhouse to be monitored in real time. Everything can be monitored from a data center. The second stage consisted in programming an IoT Cloud platform which, via the Internet, can be used to obtain the values of climatic parameters in real time and record them in a database, configure the controller's set points and intervene manually and/or automatically on the greenhouse's actuators. A WhatsApp notification system is used to notify when action needs to be taken. A prototype agricultural greenhouse is being built to test the performance and facilitate the operation of this system.

1. Introduction

Agriculture is one of the foundations of human life, because it is both a source of food and a source of raw materials. In other words, it gives us something to eat and something to sell. Therefore, growth in the agricultural sector is necessary for the development of a country's economic situation. Congolese agriculture is essentially subsistence farming undertaken by small farmers. Women make up between 64% to 70% of the active population employed in the agricultural sector; they are responsible for 70% of food production in the Congo and participate in 100% of the small-scale processing of agricultural produce. The bulk of production is used for subsistence as well as for cash income [1]. Agriculture accounts for only a tiny 5% of gross domestic product. It is practiced on only 2% of arable land (i.e., 2,000,000 hectares) and is essentially organic.

New Internet of Things (IoT) technologies, such as IoT devices (wireless sensor networks, network-connected weather stations, cameras, drones and smartphones, etc...), can be used to collect vast amounts of environmental and crop performance data, including sensor data, spatial camera data as well as human observations collected and recorded via mobile phone applications

[2, 3]. This data can then be analysed to filter out invalid data, and calculate customized crop recommendations for a specific farm.

Mobile networks are built around a cell architecture that enables the same frequencies to be used several times over a territory [4, 5]. Over the last thirty years, several generations of technology have been developed, allowing the transition from voice and text messaging services to data services, very high-speed mobile internet and connected objects. These include GSM, 3G, 4G and 5G. 4G is a technology that is characterized by increased mobility, diversity of services and higher speeds. It projects theoretical speeds of 100 Mbps for high mobility and up to 1 Gbps for low mobility [6]. Despite the limited success of 3G for the moment and the possibilities offered by 5G, mobile operators are continuing their development by launching 4G.

Agriculture is also benefiting from the development of hardware and the free or often low-cost distribution of increasingly useful applications. For example, it makes sense to use a web server (with its application, which will be programmed to plan farming tasks), the WhatsApp application (to receive notifications of actions to be carried out) and a router with a fourth-generation (4G) SIM card to help increase farmers' efficiency. The use of these new technologies and their benefits in the development of our system will not only ensure that the farming environment in our greenhouses is properly monitored, but will also improve yields [7, 8]. However, many farmers are still using traditional methods that lead to low yields in order to cope with an increasingly competitive and needy market, as is the case in Congo. As a result, agricultural production systems, particularly under glass, are becoming considerably more sophisticated. This is due to the mechanization of tools and the integration of automation and digital technology.

2. Materials and Methods

The approach developed takes into account the parameters to be configured and controlled, the different architectures and connections.

2.1. Parameter to be configured

(a) Preparing the IDE environment

It concerns the configuration of the Arduino software for programming the ESP8266 board, also known as the NodeMCU.

• *Installing the* CH340 *driver on Windows* 10:

Installation of the CH340 driver enables recognition of the NodeMCU microcontroller's serial port.

• *Configuring the Arduino IoT Cloud*:

This configuration follows the following protocol:

• *Adding a new device* - this involves connecting the NodeMCU to Arduino IoT Cloud. Once the account setup is complete, a Device ID and Secret Key are received;

• *Creating an object* - there are three elements to configure: variables, peripherals and the network (connecting the NodeMCU to the Internet);

• *Adding the variables that will be used in the code* - the aim is to create two main variables that will store the temperature and humidity values taken by their respective sensors, as well as threshold variables that will be used as references for certain calculations;

• *Configuring network identification information* - this involves entering the SSID (identification of the microcontroller from the factory), the password and the secret key generated in the procedure for adding a new device.

• *Design of the web and mobile dashboard*:

This dashboard is designed to monitor soil and air humidity data live from anywhere in the world.

• *Programming NodeMCU for sending data to the cloud*:

This involves programming the NodeMCU to read data from DHT11 as well as capacities soil moisture and sending it to Arduino Cloud. When a variable is added in Things, the sketch on the cloud is automatically updated according to the variables. In that case, part of the code is written and all that's left is to add lines for the DHT11 sensor with its library, the air temperature input variable, taking into account the connection points of the NodeMCU and the sensor itself, and also a few lines for the capacitive soil moisture sensor with its library, the soil temperature input variable, also taking into account the connection points of the NodeMCU and the sensor itself. This makes it possible to control and monitor the data from the DHT11 sensor and the capacitive soil moisture sensor using the Arduino IoT Cloud platform.

The procedure is the same for the pump and the fan.

• *Activate two-step authentication on the Arduino account*:

Arduino supports two-factor authentication via authentication software such as Authy, Google Authenticator, Microsoft Authenticator or a similar application.

After configuring the application (creating an authentication account with all your identifiers), when the application is activated, a *recovery code* appears, which is renewed every sixty seconds. This code is required to access the platform from a new terminal.

• *Activating CallMeBot messaging*:

By activating the CallMeBot service, which is free on the internet, you can send messages to WhatsApp from ESP8266. It uses a Bot that can be freely translated into a software robot. It works as an intermediary between a micro-controller or a computer or anything that can send/receive requests on WhatsApp.

• *Definition of new admin information*:

A new admin password must be set on the router for security reasons.

2.2. Parameters to be controlled

The parameters to be monitored by the sensors are as follows:

• *Air temperature and humidity*: these are among the most important variables that can be monitored from the point of view of *plant survival and growth*. This is done using the DHT11 temperature and humidity sensor;

• *Soil temperature and moisture*: these are important variables because *they facilitate plant nutrition*. This is observed using the capacitive soil moisture sensor.

2.3. The architecture

(a) Block diagram of operation

Figure 1 shows how the sensors linked to the ESP8266 card work and how the data measured by the sensors is sent.

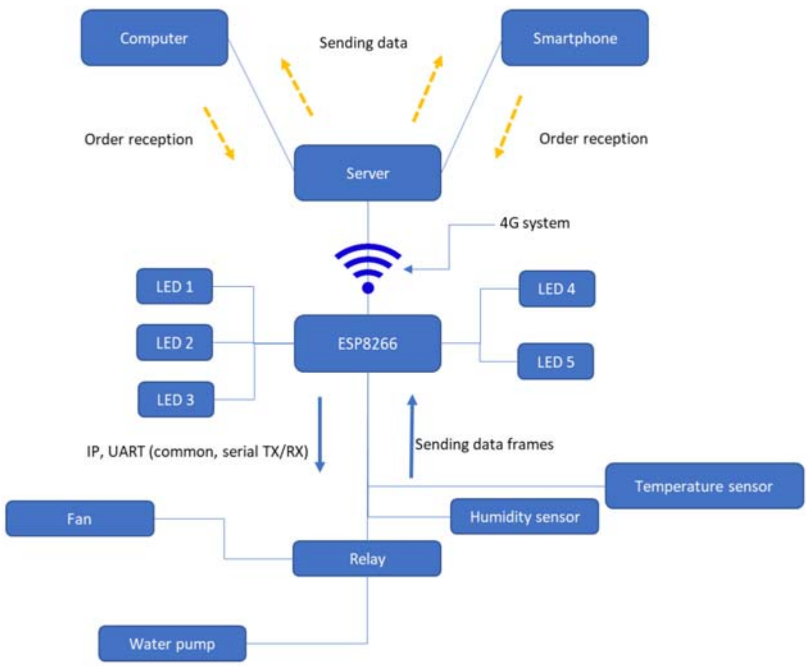

Figure 1. Block diagram of how the prototype works.

(b) Logic operating diagram

Figure 2 shows the logical operation of the method.

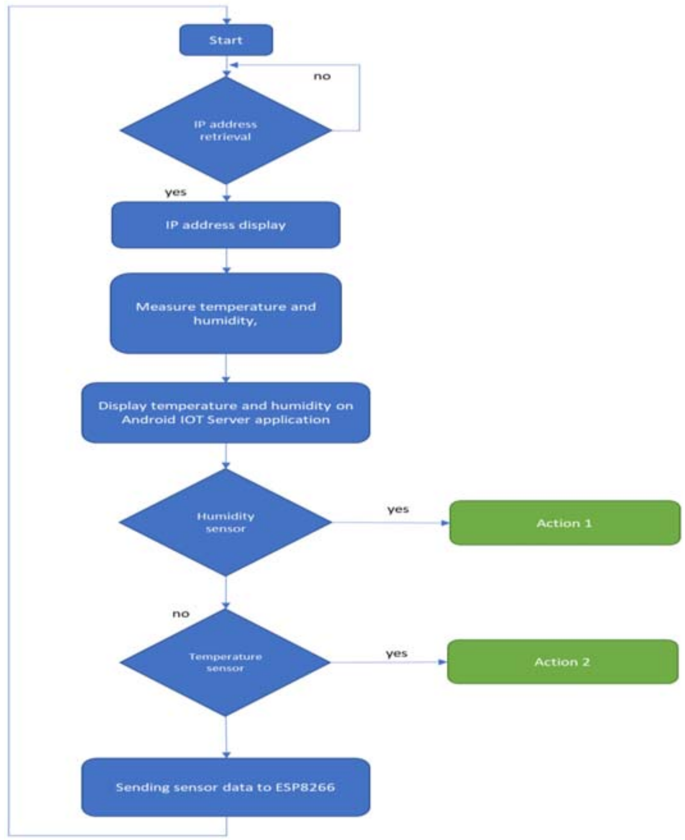

Figure 2. Operating diagram logic.

2.4. Connections

Table 1. Summary table of ESP8266 NodeMCU pin connections

Ports used	Connections	Actuators	Sensors
D0	IN1_SWITCH	Fan	
D1	IN2_SWITCH	Pump	
D3	IN3_SWITCH	Auto mode	
D4	IN_DATA		DHT11
3V	VCC		
GDN	GDN		
A0	IN_DATA		Capacitive soil moisture
GND	GND		
3V	VCC		

3. Design and Production

3.1. Design and operation of the prototype

To make it work the way we want it to, a program was uploaded to the NodeMCU. We programmed it from the web server for reasons of security, flexibility, storage, modification and remote control. To access the server, we authenticated ourselves with a Gmail account and activated the two-step authentication security. The programming language used is Arduino (similar to C and C++). Before making the complete assembly, we started by testing each sensor and actuator individually. Once that is done, it is possible to do the full assembly and test the program from now on.

(a) Electrical circuit diagram of the prototype

Figure 3 shows the electrical assembly of the prototype.

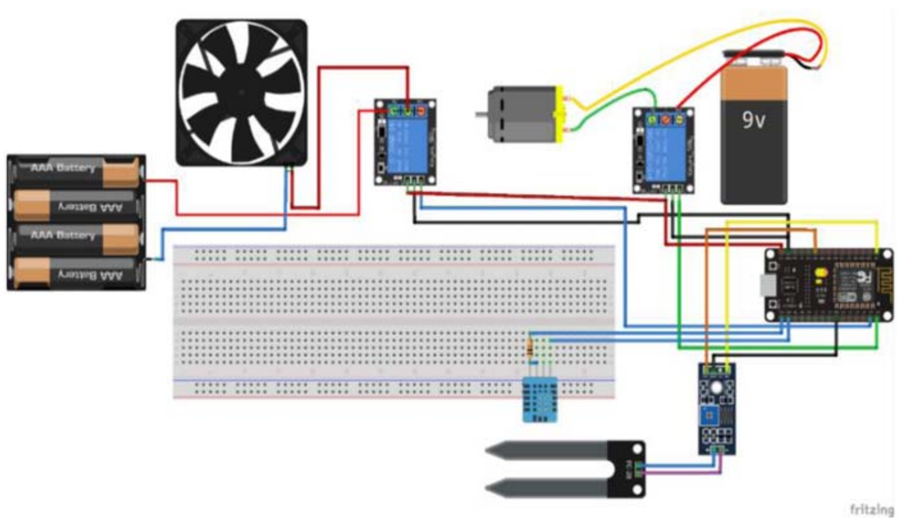

Figure 3. Schematic diagram of the assembly (produced using fritzing software).

(b) Diagram of the prototype's electronic assembly

Figure 4 shows the schematic diagram of our design.

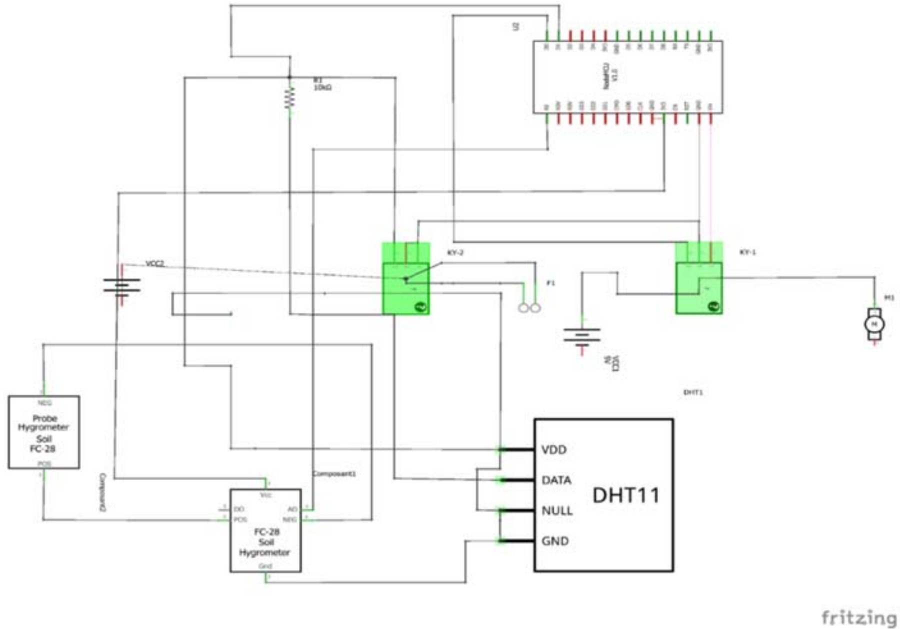

Figure 4. Diagram of the electronic assembly (produced using fritzing software).

(c) Network connection diagram

Figure 5 shows the system network connection.

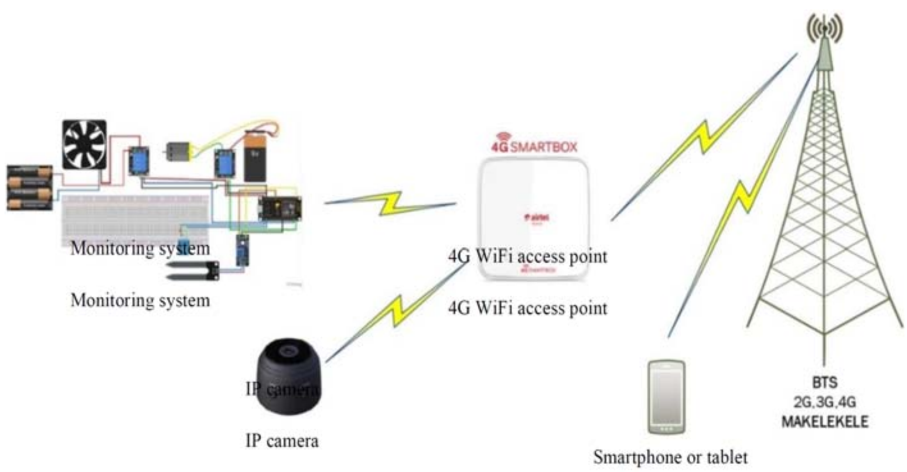

Figure 5. Remote piloting system network connection architecture.

Once the various data have been captured by the sensors, this information is transmitted to the micro-controller. Once this phase is complete, the information received by the micro-controller is first interpreted by the latter before being transmitted to the web server.

To connect to the Internet, the micro-controller connects to the WiFi network using the identifiers entered in the program (or sketch) and checks its device ID and secret key.

Once at this level, 4G technology comes into play. In other words, the UE (represented by our router) connects to the eNodeB. 4G comes into play in our project thanks to the 4G SIM card router. Once the UE is switched on, it issues a request. It connects to the eNodeB covering its area. The signal is then sent to the HSS via the MME. The HSS, which is responsible for verifying the subscriber's identity profile, carries out the verification. Once the profile attached to the SIM card has been validated by the HSS. The signal goes to the SGW, and then to the PGW. It is then verified and billed at the OCS before returning to the PGW (which assigns it an IP address) and going to the SGI, and finally onto the Internet to reach the web server.

Figure 6 shows the architecture for personal use.

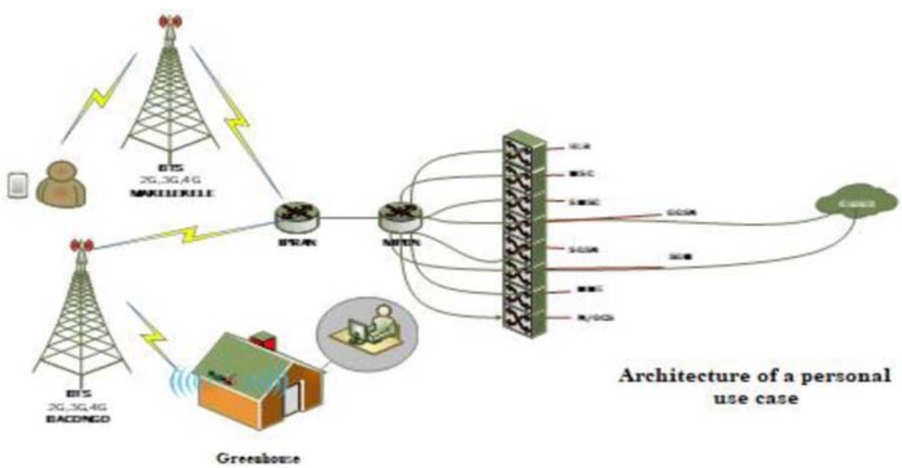

Figure 6. Architecture of a personal use case.

3.2. Producing the prototype

(a) Overview of the prototype

Figure 7. Final assembly with its boxes.

(b) Switching on

Start-up is coordinated by the micro-controller. Note that the micro-controller is the first point of arrival of the power supply. Concerning command transmission, reception and signal processing (conversion of signals into understandable data). All the sensors and the relay are switched on simultaneously.

Once the sensors are switched on, they perceive the various variations in their environment. The signals from these sensors are then sent to the NodeMCU for processing.

Once processed, the NodeMCU, connected to the Internet via an access point, sends them to the cloud. They are then displayed on the web server interface.

The control section remains powered as long as the relay remains connected to the circuit. The ports in the power section are activated according to the command issued by the micro-controller.

With 4G, one of the essential conditions is that our system must be in an area where there is effective network coverage.

Figure 8 shows an overview of the dashboard.

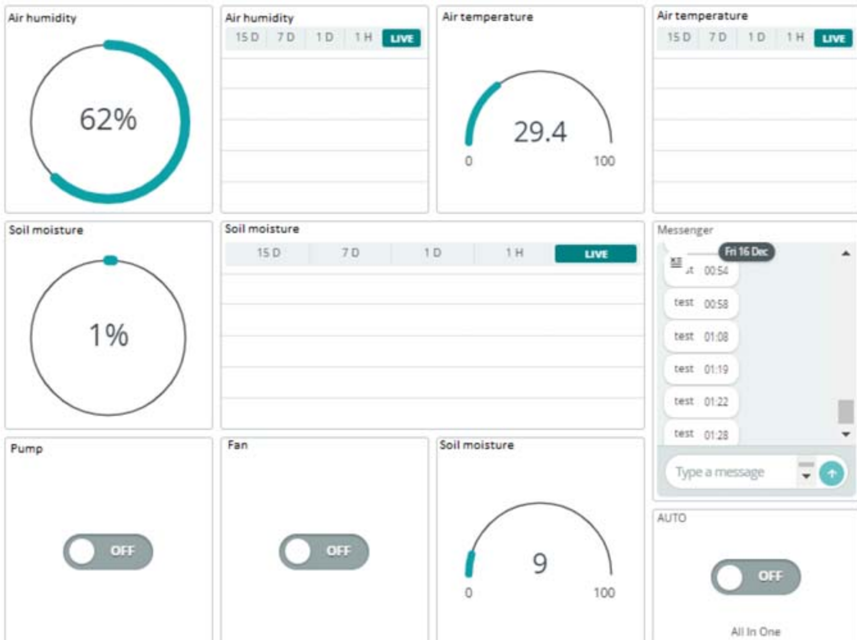

Figure 8. Presentation of the dashboard.

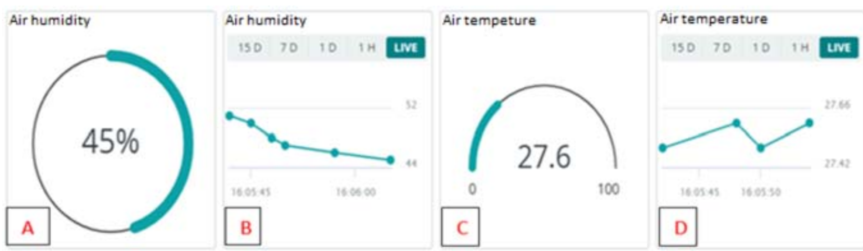

Figure 9. Parameter values at air level.

- A: Percentage of humidity.
- B: Variation curve of the percentage of humidity in the air in relation to time.
- C: Value of the air temperature over 100 degrees Celsius.
- D: Variation curve of air temperature with respect to time.

Figure 10. Parameter values at ground level and cat.

- E: Percentage of soil moisture.
- F: Soil moisture value curve.
- G: Chat for announcing greenhouse status.

The image below shows the part of our dashboard that manages the actuators.

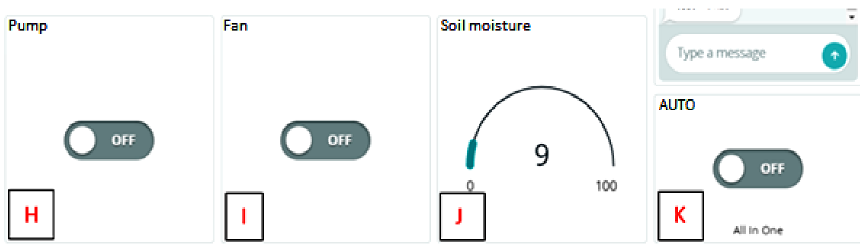

Figure11. Actuator handling.

- H: Irrigation pump ignition switch.
- I: Fan ignition switch.
- J: Percentage of soil moisture.
- K: Switch for launching automatic mode.

We can also download the latest data on the greenhouse's operating parameters for better exploitation. This information is very useful for farmers and statisticians to know how the plant has experienced certain events and times in its growth. All data can be used in Excel.

The proposed prototype offers significant advantages in terms of:

- Safety:

✓ *Communication encryption*: Arduino IoT Cloud uses SSL/TLS encryption to protect communications between devices and the cloud, preventing unauthorized third parties from intercepting or modifying the transmitted data.

✓ *User authentication*: via a username and password to protect access to data and cloud functions. Arduino IoT Cloud also features two-step connection activation.

✓ Managing access rights.

✓ Security updates to correct vulnerabilities and protect user data.

- Comfort:

✓ Controls are triggered automatically according to the greenhouse's climatic parameters, or manually. These include switching on the water pump when the soil becomes dry enough.

✓ The data is stored in real time in the Arduino IoT database using Android studio.

✓ In order to facilitate the study of greenhouse cultivation, the prototype of a mini agricultural greenhouse is intelligent and supervised by an Internet of Things system under the direction of the Arduino IoT Cloud platform.

✓ The prototype works with two applications: a Web application and an Android application, which can be used to obtain data on parameters of climatic changes such as temperature and humidity, and to take action if necessary.

✓ A WhatsApp notification system has been integrated into the CallMeBot API to provide information on whether or not the cooling system needs to be activated.

✓ Automatic mode can be activated.

4. Conclusion

Our work involved designing an embedded system for remote control of an agricultural greenhouse via a 4G broadband mobile phone system. This system uses a network of sensors distributed around the greenhouse to monitor the climatic parameters of the greenhouse environment in real time, and the data is transmitted via the internet using 4G to an IoT Cloud platform, where it is stored in a database. The system also sends notifications via WhatsApp to advise farmers on what action to take.

This system enables farmers to control and regulate their greenhouse remotely using their mobile phone or computer. A prototype greenhouse has been developed to test the system.

By combining all these technologies, the monitoring of an agricultural greenhouse enables precise and efficient management of watering on farms by accurately measuring soil moisture and adjusting irrigation practices by controlling the frequency, duration and intensity of watering according to the actual needs of the crops.

Due to this intelligent approach based on accurate data, farmers can save water, reduce irrigation costs and improve plant health.

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