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IoT Technology for Monitoring and Control of Smart Greenhouses

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Abstract

A greenhouse is a covered structured area which protect the plants from extreme weather condition, providing a controlled environment for their growth and cultivation. The innovative Internet of Things (IoT) technology uses a series of sensors connected to a central computer to control the greenhouse environment. Greenhouse sensor systems include elements that monitor and control temperature, humidity, soil moisture, lighting, and external weather conditions. The research aims to design a greenhouse monitoring and control system based on the Internet of Things (IoT). In smart greenhouses, IoT involves sensors, devices, and information and communication infrastructure for real-time monitoring, data collection, and processing to control the environment inside the greenhouse unit. Controlled greenhouses, supported by computer technology, can enhance quality and increase crop yields. This research involves three greenhouses that are independently monitored and controlled through an Internet of Things (IoT) cloud platform. Cloud monitoring facilitates better integration of devices across different geographical locations.

Keywords: IoT, Technology, Real-time data monitor, Sensor capabilities, cloud platform, Smart farming, mobile application.

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1. Introduction

An IoT mechanism for connecting physical things to the Internet. Generally, IoT comprises three key levels of components: i) Edge functions, where sensors and actuators are attached to physical objects. ii) Data gateways, which serve as a mechanism for receiving sensed data from peripheral devices and transmitting and receiving information from network servers. iii) Data management and analysis, involve the collection, linking, analysis, and utilization of data based on a (cloud) server [1-5]. Smart agriculture involves managing farms using modern information and communication technologies to enhance the quantity and quality of products. Advances in greenhouse technologies provide science-based solutions for optimal plant production by adjusting internal climate growth factors, such as temperature, light intensity, and CO2 concentration [6,7]. Greenhouses consume significant amount of energy compared to other agricultural businesses; therefore, the reduction of energy consumption in agricultural greenhouses is a fundamental goal for sustainability. Smart greenhouse system provides monitoring and control capabilities that do not require much manual interaction, because it uses a wide variety of sensors, controllers & intelligent system for observation [8-13].

1.1 Objective of the Project

The research aims to leverage IoT sensors and automation by providing IoT solutions to increase productivity, reduce production costs, improve quality control and minimize crop wastage. By implementing IoT- based solutions, the unit can collect real-time data about the process, such as temperature, humidity, and moisture levels, and analyse it to optimize the process. The Solar power model in the greenhouse provide a sustainable solution for farming using renewable energy to power different farming approaches and minimise the impact on environment.

1.2 Scope of the Project

This proposed study serves as a framework for IoT solutions, incorporating smart sensors and a cloud platform that integrates various hardware components. With this model, users can implement a smart system for monitoring temperature, humidity, soil moisture, and light intensity crucial for plant growth and development. Details of the sensors and the control system are as follows:

i. Light Sensor: Ensures proper lighting of the plant. The intensity of the light can be adjusted according to the plant's requirements.

ii. Temperature and humidity sensor: Regulates greenhouse temperature and humidity that is important for maintaining suitable environmental conditions for plant growth.

iii. Soil Moisture Sensor: This sensor is used to measure soil moisture, any drop or increase in moisture is recorded and corrected.

All the three sensors are customizable to match specific plant growth conditions and requirements.

The control system primarily focuses on controlling parameters such as temperature, humidity, and soil moisture content to promote healthy plant growth and increase yield. Its main function is to report information about the mentioned soil parameters and take counter measures to bring them to the appropriate level, and this information display is realized using a mobile application using IoT solutions and sensor networks.

The rest of the paper is organized with the proposed work and its architectural model in section 2, results and discussion in section 3, and the conclusion in section 4.

2. Proposed Work

2.1 Architecture of the Model

The prototype unit comprises three separate greenhouse models, independently monitored and controlled through an IoT-based automation set-up. All the models have a solar-powered supply unit, Arduino Mega controller, and a Node MCU Wi-Fi module. Different sensors are used to measure temperature, humidity, nutrient levels, moisture, and light. The microcontroller unit is programmed to receive and transmit the sensor data to a cloud platform for analysis. Control program is written to take appropriate action, such as actuating water pumps, nutrient pumps, exhaust fans, and light intensity of each greenhouse units.

The platform also provides real time-based graphs and remote user controls for optimizing conditions across units. Overall, it enables cost-effective IoT-based automation solution for multiple greenhouse operation. The Figure.1 shows the architecture of the proposed model.

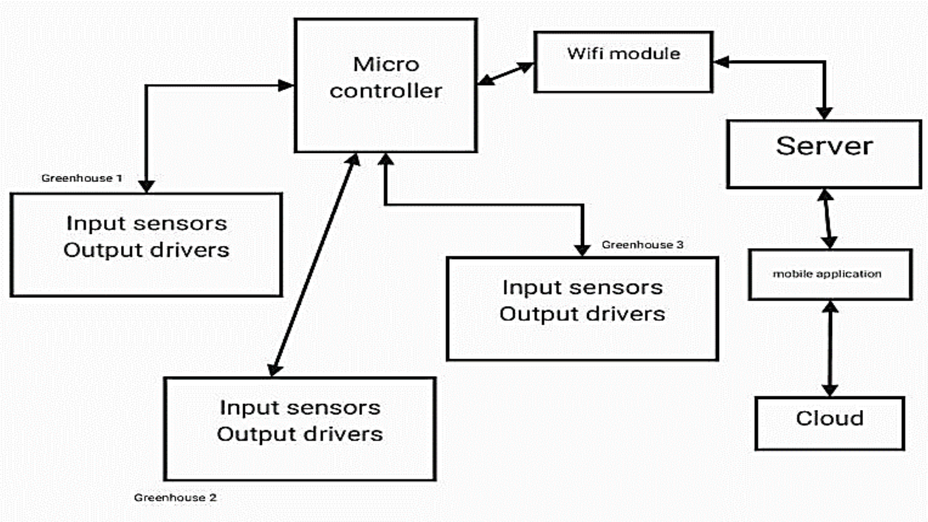

Figure 1. Architecture of Proposed Model

2.2 Block Diagram

The schematic block diagram of all the three networked greenhouse models is shown in Figure 2. All the three greenhouses are independently monitored and controlled using IoT-based automation. The power supply for each greenhouse is given through solar supply unit. A charge controller, a 12V battery, and an adapter primarily uses the solar energy to power the system as well as serve as a backup power source for further use. An Arduino Mega functions as the main controller in each greenhouse, connected to a Node MCU Wi-Fi module for IoT connectivity. This enables remote monitoring and control of all the three greenhouses from a centralized unit. The sensors are distributed in the three greenhouses are similar for consistent measurements, while allowing flexibility of certain parameters if needed. These include TDS sensors for quantifying soil nutrient levels, DHT11 for temperature and humidity monitoring, soil moisture probes and light sensors.

The collected data from the sensors is transmitted to the cloud platform using the Wi-Fi capabilities of the MCU node. The centralized interface then uses intelligent control algorithms to analyse this data and activate the appropriate controllers in each greenhouse accordingly. Such actuators include water pumps, nutrient pumps for fertilization, exhaust fans for ventilation as needed, and grow lights to supplement natural sunlight. This comprehensive approach to automation and the Internet of Things maintains an optimized environment in each individual greenhouse unit. Additionally, the platform interface provides real time graphs and previews of the conditions in the three greenhouses. Remote users can also override certain control parameters for specific greenhouses when needed, enabling personalized farming initiatives. The list of components used for construction of the work shown in the Table .1 below.

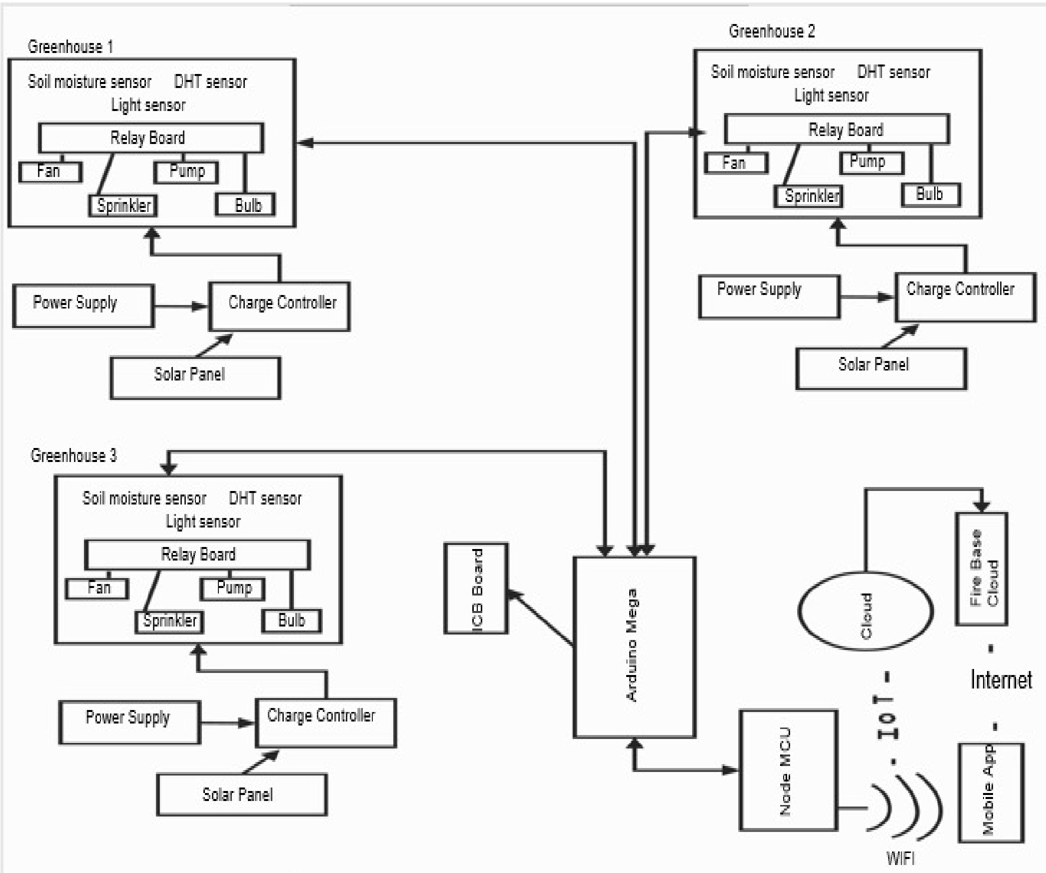

Figure 2. Block Diagram of the Model

Table 1. Hardware Components

S.No	Hardware Components Used	Uses
1.	LM2596 DC-DC Buck Converter Step Down Module	Voltage Regulation
2.	Exhaust Fan	Ventilation
3.	Mega 2560 ATmega2560-16AU Board	Controller

4.	Water Pump	Irrigation
5.	Monocrystalline Solar Panel	Power Generation
6.	Channel Relay Board	controls the power supply to various components
7.	LDR Sensor Module	Light Sensing
8.	Soil Moisture Sensor Module for Arduino	Soil Moisture Sensing
9.	DHT11 Temperatures and Humidity sensor Module	Temperature and Humidity Sensing
10	LED Light Injection Module	Optimize the lighting conditions

2.3 Methodology

Smart greenhouse agriculture using IoT solutions and embedded systems not only intelligently monitors but also controls the climate. This eliminates the need for human intervention. The whole setup is to implement an IoT environment with a mobile application and sensor networks. The developed model is user-friendly with the aim of making it as easy as possible to operate through a mobile application, to monitor and control the requirements of greenhouse management. Figure.3 illustrates the flowchart of the logic implementation.

2.4. Implementation

- **Software Setup**: This includes software installations, Wi-Fi connection and server connections. First step is to establish Wi-Fi connection, Once the Wi-Fi is successfully connected, sever connection(fire-based cloud) is established as well.

- **Hardware Setup**: The main controller that is used is Arduino mega along with sensors and actuators. The sensors that are used in this research are temperature and humidity sensor, light sensor, and moisture sensor that are connected to the controller through ports available.

- **Sensor Data Collection**: C codes were developed to collect data from the sensors at regular intervals.

- **Actuator Control**: When temperature of the greenhouse exceeds over a certain level or range then the fan is turned on and if the level reaches to the specific range, it is turned off. Similarly, the other parameters are controlled.

- **Remote Access**: The sensor data is given to the microcontroller which is Arduino mega and Wi-Fi ESP 8266. The data that is stored in Arduino mega is sent to Wi-Fi module via serial communication. And the IoT integration is observed between the microcontroller and the cloud(fire-base cloud). Where the data is stored and uploaded which with the help of the local server the user can access the data on the mobile application remotely.

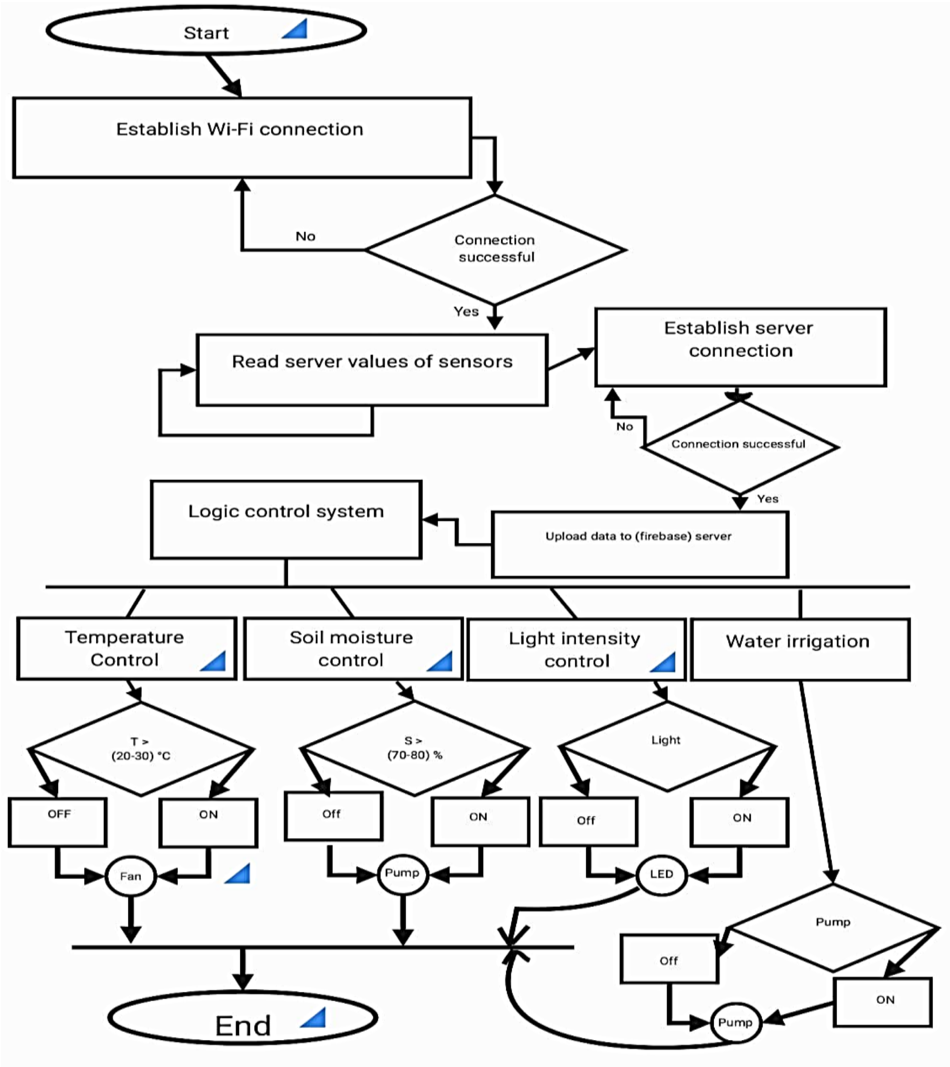

Figure 3. Flowchart of the Logic Implementation

3. Results and Discussions

3.1 Greenhouse Monitor and Control Unit Model

The Figure.4 and 5 below shows the hardware model of the smart greenhouse. It uses a set of sensors such as temperature and humidity sensor, humidity sensor, light sensor. These sensors are used to monitor and provide real-time data on the environmental conditions in the greenhouse. We use fire base cloud to monitor the three greenhouses and display the data in real time in the mobile application, which is achieved by IoT solutions. When the soil dehydrates, the moisture sensor detects it and is immediately alerted, and the water pump pumps water to maintain a certain amount of moisture in the soil, and similarly with other parameters, when the temperature exceeds the appropriate amount, the sensor is triggered and the fans are turned on to reduce the temperature, it everything contributes to the healthy growth of plants and thus to an increase in their yield and quality. The mobile application was developed using the Flutter app. The Figure. 6 shows the screen shots of the mobile application developed.

Figure 4. Prototype 1 Front View of Hardware Model Unit

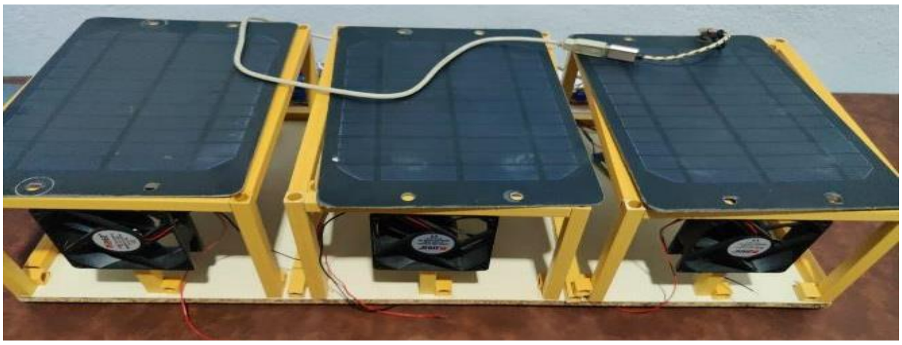

Figure 5. Prototype 2 Rear View of Hardware Model Unit

3.2 Results: Screen Shot

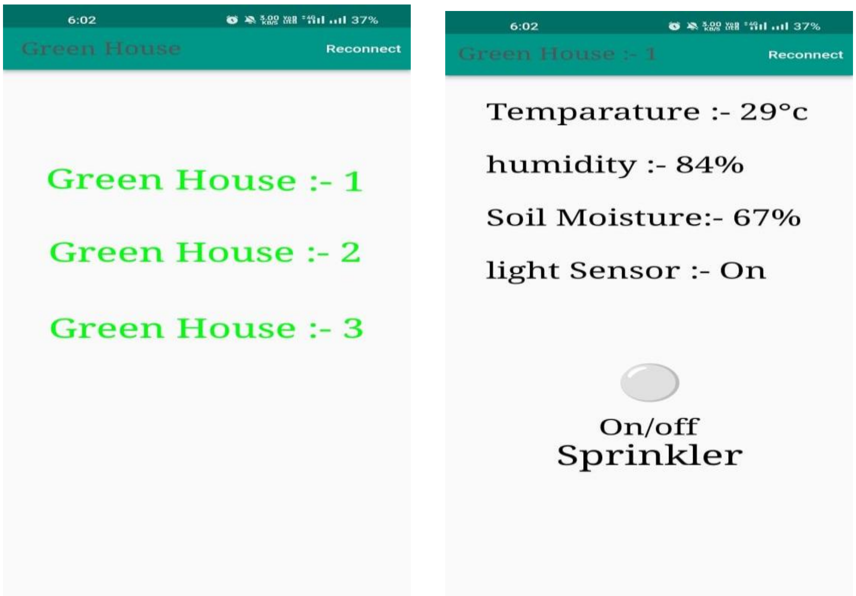

Figure 6. Mobile Application

4. Conclusion

The smart greenhouse automation monitoring and control system uses sensors, GSM, and IoT to estimate and update various parameters in the greenhouse This optimization of resources is particularly beneficial, as all models are designed to consume low power and offer easy reconfigurability Leveraging sensor nodes, internet connectivity, and cloud integration allows for instant updates of parameters, facilitating improved yield for farmers. Implementing this method in agriculture has the potential to increase overall crop yield, and the favorable price ratio makes this approach accessible to a majority of farmers.

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