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LoRa Based Green House Monitoring and Control System using IoT

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Abstract: This project proposes a distributed, multi-span greenhouse monitoring and control system using LoRa communication and IoT technology to enhance agricultural productivity. Greenhouses provide a controlled environment for optimal plant growth while protecting crops from extreme weather conditions. The system continuously monitors key environmental factors such as temperature, moisture, illumination, pressure, and humidity. Automated control of devices like exhaust fans, sprinklers, and lighting systems is implemented based on predefined logic and climate conditions. Smart Alerts notify farmers of environmental stress or hardware failures through real-time app notifications. Additionally, Automated Contingency Protocols and Weather-Linked Automation ensure proactive responses to emergencies, minimizing risks. By integrating real-time monitoring and intelligent automation, this system optimizes crop growth, improves resource efficiency, and enhances resilience against environmental uncertainties.

IndexTerms - LoRa, IoT, Greenhouse Monitoring, Real-Time Control, Resource Optimization, LoRa Communication, Low-Power Connectivity, Environmental Sensing, Automated Alerts, Precision Agriculture, Sustainability, Smart Farming.

I. INTRODUCTION

This project proposes a LoRa-Based Greenhouse Monitoring and Control System Using IoT to enhance the greenhouse farming experience through an Environmental Management Automation process. A greenhouse is a controlled environment for the growth of plants; in such an arrangement, the manual methods are found to be quite ineffective. The proposed system automates exhaust fans, sprinklers, and lighting based on real-time data by continuously monitoring temperature, humidity, illumination, soil moisture, and atmospheric pressure. Smart Alerts enhance productivity by informing the farmer about environmental stress or equipment malfunctions. In case of an emergency, Automated Contingency Protocols take over. Weather-Linked Automation Modifies greenhouse parameters according to weather predictions. This is all made possible by the use of LoRa technology, ensuring effective, scalable, and affordable management of greenhouses.

II. RELATED WORK

TITLE: LORA WAN-BASED INTELLIGENT MULTI-GREENHOUSE MONITORING AND CONTROL
AUTHORS: ABDELKADER MEZOUARI, HAJAR ELKARCH, CHAIMAE HAOUL, HAMAD DAHOU AND RACHID ELGOURI
PUBLICATION: E3S WEB OF CONFERENCES VOLUME 469, ICEGC'2023

DESCRIPTION:

This study presents a multi-greenhouse LoRa-WAN technology-enabled monitoring and control system to improve precision farming. The system involves wireless networks of sensors to monitor environmental conditions such as temperature, humidity, CO_2 level, and moisture in the soil. LoRa-WAN is employed to communicate these readings to a centralized web-based platform for remote supervision and automatic control of conditions in greenhouses. The research identifies the benefit of LoRa-WAN connectivity in enabling low power usage but with long-distance communications. Real-time visualizing of data is facilitated by the proposed system while enabling multi-greenhouse scaling as well as automatic mechanisms of climate control for enhanced agricultural yield.

DESCRIPTION:

This project looks at how LoRa technology may be employed for real-time condition monitoring and control of greenhouses. There are two parts of the system:**1.** Measurement and Control Module – Employing temperature, moisture sensors linked to a LoRa end-device to monitor and transmit readings.**2.** Monitoring and Control Center – LoRa gateway captures information and transfers it to cloud by Wi-Fi for remote access. The study identifies LoRa's advantage in allowing low power consumption, far-distance communications, and wireless automation for smart farming. The proposed system achieves maximum greenhouses' efficiency by automating irrigation, ventilation, and measurement of environmental conditions.

DESCRIPTION:

This study focuses on how LoRa-WAN technology is employed in precision farming to monitor and automate greenhouses more efficiently. Research encompasses the implementation of wireless sensor networks to monitor temperature, moisture in the soil, CO_2 levels, and humidity to guide farmers to make more strategic decisions for maximum crop yield and resource utilization. The system consists of LoRa-WAN enabled sensors that collect environmental data in real-time and communicate it to LoRa gateway that sends it to cloud-based platform. Low power, low infrastructure demand, and far-distance communications make it ideal for mass-scale greenhouses. By integrating IoT-based remote monitoring technology, the research points to the possibilities of automated climate control and data-based agricultural management. According to the research, LoRa-WAN technology has the potential to make modern greenhouses much more efficient, more sustainable, and more scalable.

TITLE: INTELLIGENT AGRICULTURE GREENHOUSE MONITORING SYSTEM USING IOT TECHNOLOGY
AUTHORS: LIU DAN, CAO XIN, HUANG CHONGWEI, JI LIANGLIANG
PUBLICATION: 2015 INTERNATIONAL CONFERENCE ON INTELLIGENT TRANSPORTATION, BIG DATA & SMART CITY

DESCRIPTION:

This research focuses on IoT-based greenhouses' monitoring systems. The system continuously monitors temperature, humidity, CO_2 level, and moisture in the soil by using wireless sensors to create suitable environmental conditions for crop growth. By leveraging LoRa technology to stream in real-time readings from sensors to a cloud platform, greenhouses' conditions can be remotely monitored and managed by growers in an effective manner. Mechanisms of automatic control of climates where pre-programmed thresholds trigger adjustments that must be implemented have been focused on in research. The integration of LoRa-WAN technology with IoT maximizes resource utilization, increases agricultural yield, and makes environmentally friendly farming processes possible. All these serve to cut cost of operations, conserve power and water, and increase crop yield, thus making it an ideal solution for future smart farming.

II. EXISTING SYSTEM

Existing greenhouse monitoring and control systems include manual monitoring, wired sensor networks, ZigBee/Wi-Fi-based systems, GSM/cloud-based IoT solutions, and LoRa-WAN based systems.

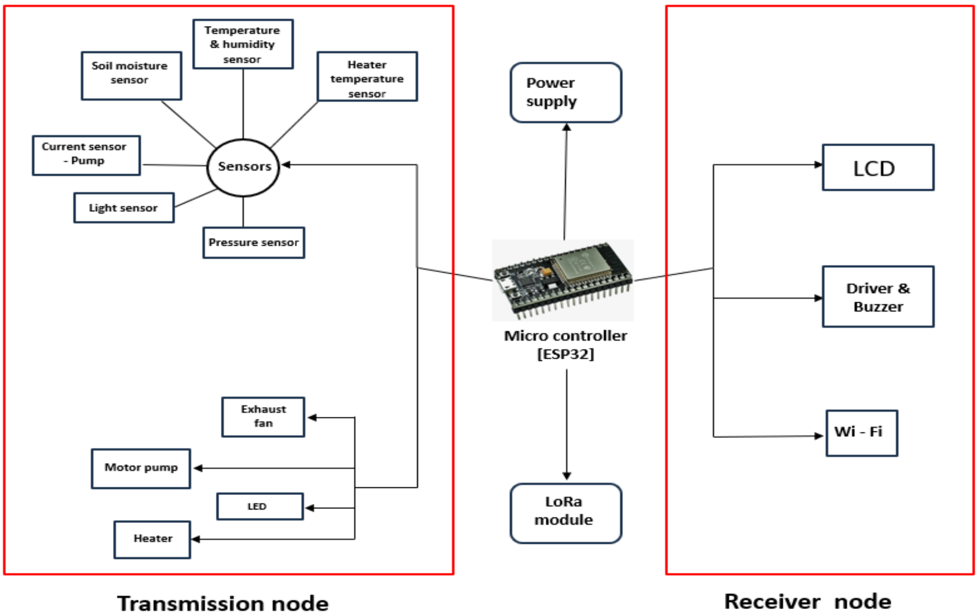
1. **Manual Monitoring Systems –** Traditional greenhouses rely on manual observation and adjustments using basic instruments like thermometers and hygrometers. These systems are labour-intensive, error-prone, and inefficient, lacking real-time data access and automation.
2. **Wired Sensor-Based Systems –** Early IoT-based greenhouse systems use wired sensors to monitor temperature, humidity, CO_2 levels, and soil moisture. The data is processed by a centralized controller, which can trigger automated responses. However, these systems require extensive wiring, have high installation and maintenance costs, and lack scalability for multi-greenhouse operations [4].
3. **ZigBee/Wi-Fi-Based Wireless Sensor Networks (WSNs) –** Wireless alternatives use ZigBee, Wi-Fi, or Bluetooth to connect greenhouse sensors to a control unit. These systems enable remote monitoring and automation but suffer from limited communication range (10-100 meters), high power consumption, and network interference, making them unsuitable for large-scale greenhouse networks [4].
4. **GSM/Cloud-Based IoT Systems –** Advanced monitoring systems use GSM modules to transmit real-time sensor data to a cloud server, allowing farmers to access greenhouse conditions remotely via mobile apps or web dashboards [4]. While these systems provide automation and real-time control, they depend on stable internet connectivity, have high data transmission costs, and consume significant energy.
5. **LoRa-WAN Based Greenhouse Monitoring Systems (Emerging System) –** Modern precision agriculture systems leverage LoRa-WAN technology for long-range, low-power data transmission. LoRa-WAN enabled wireless sensors continuously monitor greenhouse parameters and send real-time data to a LoRa gateway, which then transmits it to a cloud-based platform for remote access and automation [1][2][3]. Automated climate control mechanisms adjust irrigation, ventilation, and lighting based on sensor readings, reducing manual intervention and optimizing resource utilization. LoRa-WAN based systems overcome the limitations of previous methods by enabling cost-effective, scalable, and energy-efficient greenhouse management [1][3].

III. PROPOSED SYSTEM

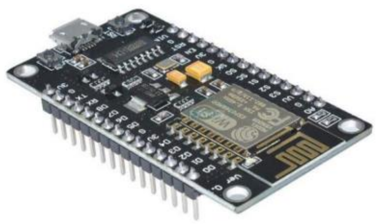
The proposed system is an LoRa-based smart green-house monitoring and control system that utilizes IoT technology to improve agricultural yield. There is a Transmission Node that comprises several environmental sensors such as temperature, humidity, moisture in the soil, light, and pressure sensors that monitor conditions in the green-house on a continuous basis. There is an ESP32 microcontroller that processes all the readings and controls actuators such as the exhaust fan, motor pump, heater, and LED in accordance with pre-programmed rules. There is a LoRa module that sends all of these accumulated readings to the Receiver Node where it is displayed on an LCD display for display in real-time. There is Wi-Fi connectivity for cloud-based remote monitoring integrated in the system while a buzzer and alert system warns farmers of extreme conditions. Through Automated Contingency Protocols and Weather-Linked Automation, the system responds to environmental changes in advance, maximizes crop yield, conserves resource, minimizes human interference, thus constituting sustainable smart farming in its true sense.

Module Description: A module is a Hardware and software component or part of a program that contain one or more routines.

IV.BLOCK DIAGRAM:



NODEMCU (ESP8266):



The ESP32 is a rich feature microcontroller used as the smart greenhouse control and monitoring system's central processor. It has Wi-Fi and Bluetooth for seamless interconnectivity of sensors, actuators, and cloud platforms. ESP32 processes environmental sensors' real-time readings, executes rules of automation, and sends messages through the LoRa module for far-distance communications. Motor pumps, heaters, exhaust fans, and LED lights are further controlled by the ESP32 based on pre-defined conditions. Low power consumption, high computing power, and multi-I/O interfaces by the ESP32 make it easy to have effective and reliable operation of the smart greenhouse system.

LoRa MODULE:

The LoRa (Long Range) module is a crucial component in the greenhouse monitoring system, enabling long-range, low-power wireless communication between the transmission and receiver nodes. It allows sensor data from the greenhouse environment to be transmitted efficiently to a remote monitoring center or cloud platform. LoRa technology ensures reliable communication over large distances while consuming minimal power, making it ideal for agricultural applications. The module is integrated with the ESP32 microcontroller to send real-time data about temperature, humidity, soil moisture, and other environmental parameters, allowing farmers to monitor and control greenhouse conditions remotely.

DHT22 SENSOR:

The Temperature and Humidity Sensor tracks the surroundings' temperature and relative humidity in the greenhouse. It gives instant feedback to create ideal conditions for crop growth. The sensor detects changes in temperature to manage heaters, exhaust fans, and ventilation to create ideal conditions. Humidity readings also contribute to irrigation and misting system regulation to create ideal moisture conditions. Through microcontroller integration, the sensor makes automatic climates adjustment to enhance plant growth, resource conservation, and general performance of the greenhouse.

SOIL MOISTURE SENSOR:

The Soil Moisture Sensor measures moisture in the soil to offer adequate irrigation for crop growth. It measures moisture by testing capacitance or conductivity of the soil and sends the measurement to the microcontroller. According to readings, irrigation might be automated by energizing the motor pump if moisture drops to a set level. Overwatering or underwatering is avoided by this sensor while allowing for more effective utilization of water for adequate crop growth in the greenhouse.

LIGHT SENSOR:

The Light Sensor measures the degree of ambient light within the greenhouse to create ideal conditions for plant photosynthesis. It measures the level of light present and sends the readings to the microcontroller. Depending on these readings, the system has the potential to control artificial lighting in the form of LEDs to offer additional lighting if necessary. Proper photosynthesis is achieved through this feature, energy is conserved, and maximum plant growth occurs in all environmental conditions.

PRESSURE SENSOR:

The Pressure Sensor measures environmental or fluid pressure in the greenhouse environment. It aids in monitoring changes in air pressure that may impact plant growth in addition to greenhouse balance. It is used further to monitor water pressure in irrigation to offer effective watering dispersal. Through provision of immediate pressure readings, the system is able to coordinate ventilation, maintain uniform conditions for growth, and prevent possible failures of apparatus caused by changes in pressure.

CURRENT SENSOR [PUMP]:

The Current Sensor measures the flow of electrical current through appliances like motor pump, heater, and other electronic components in the greenhouses to provide proper operation by preventing damage caused by power overdraws. The sensor assists in energy consumption monitoring, power maximization for efficiency, and alarming in situations of electrical fault to make the system more secure and dependable.

HEATER TEMPERATURE SENSOR:

The Heater Temperature Sensor monitors the temperature of the heating unit to provide proper performance and to prevent overheating. It continuously senses heater surface or surrounding air temperature and sends signals to the microcontroller. If it realizes that the temperature has reached more than a predetermined limit, the system has the potential to control or turn off the heater to offer a secure and ideal environment. Through this sensor, energy wastage is prevented, crops from getting over-exposed to heat, and general performance of green-house climate control system is maximized.

EXHAUST FAN:

The Exhaust Fan is part of good ventilation in the greenhouse. It ensures temperature, humidity, and CO_2 balance by clearing warm, moist or stale air and drawing in fresh air. Air circulation is maximized by it, mold formation is prevented, and conditions for maximum plant growth are ensured. The exhaust fan is on automatic control through sensors where temperature or humidity exceeds set limits to create a uniform environment.

MOTOR PUMP:

The Motor Pump facilitates automatic irrigation of the greenhouse. It sucks in water from a tank and directs it to plants based on readings from the moisture sensors in the soil. As the moisture level in the soil drops to a predetermined level, the pump is activated to provide plants with sufficient water for adequate nourishment for their growth. Automation saves water, makes irrigation more effective, and avoids human interference in irrigation processes.

HEATER [Bulb]:

In this configuration, the heater is integrated through a bulb that emits not only warmth but also light to create suitable environmental conditions in the greenhouse. The bulb is used as a warmth producer to sustain the ideal temperature within the established limits even in low weather conditions. It is temperature sensor-controlled to turn on whenever the level of temperature decreases to a predetermined level and turn off once the requisite warmth has been achieved.

LCD [LIQUID-CRYSTAL DISPLAY]:

The LCD display is used to display environmental conditions in real-time such as temperature, air moisture, moisture in the soil, and system status. It provides growers or operators with a graphical interface to monitor conditions in the greenhouse in real-time. The LCD gives instant access to critical details without requiring an external unit.

LED [LIGHT EMITTING DIODE]:

The LED is used for horticultural lighting in the greenhouse to provide assistance to plants in low-intensity conditions for their growth. It might also be used as a status indicator or for warnings. The LED operates on readings from light sensors to turn on whenever natural conditions cannot provide enough light for photosynthesis to take place.

BUZZER:

The buzzer is employed as an alarming indicator of environmental conditions, malfunction of hardware, or crossing of thresholds. It emits sound signals in case predetermined conditions of extreme temperature or low moisture in the soil level are attained. This facilitates quick decision-making as well as prevention of crop damage in advance through timely intervention.

LoRa COMMUNICATION AND DATA TRANSMISSION

LoRa communication is implemented using the LoRa-WAN protocol, which enables long-range, low-power wireless data transmission. The ESP32 and Arduino Uno communicate with the LoRa module (Ra-02) via SPI (Serial Peripheral Interface) or UART (Universal Asynchronous Receiver-Transmitter) to ensure stable data transfer. The transmitter node sends sensor data through the LoRa module, and the receiver node processes and displays it for local monitoring. This method ensures low-power, long-distance communication, making it ideal for agricultural applications where Wi-Fi or cellular networks may not be available.

Web-Based Monitoring and Cloud Integration

The system features a web-based dashboard for real-time monitoring and remote control of greenhouse conditions. The dashboard allows users to view sensor readings such as temperature, humidity, soil moisture, and light intensity. It is developed using HTML, CSS, JavaScript, and PHP, which provide an interactive interface and backend functionality (https://dreampixelz.in/25/iot25/dashboard.php). PHP scripts handle data requests, while a MySQL database stores sensor readings for historical analysis and performance tracking. The ESP32 sends data to the web server using HTTP requests or MQTT protocol, enabling seamless cloud integration.

Data Visualization and Control

To enhance local monitoring, the system includes an LCD display (16x2) that shows real-time sensor values at both the transmitter and receiver nodes. The LCD display is programmed using the Liquid-Crystal library in Arduino IDE, allowing clear and structured data presentation. The system also supports MQTT (Message Queuing Telemetry Transport) or HTTP protocols for transmitting data between the IoT devices and the web server. These protocols ensure low-latency data exchange, allowing users to receive instant notifications and alerts if critical greenhouse conditions are detected.

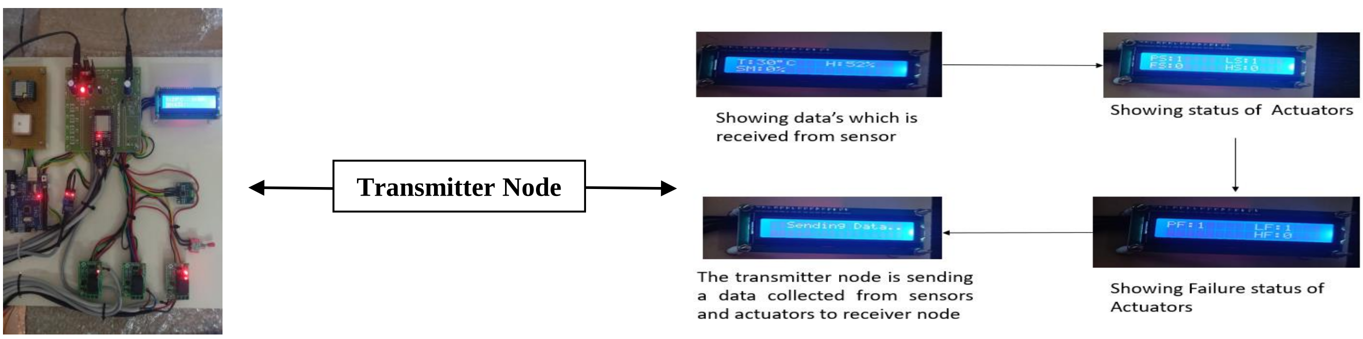
Additional Software Tools

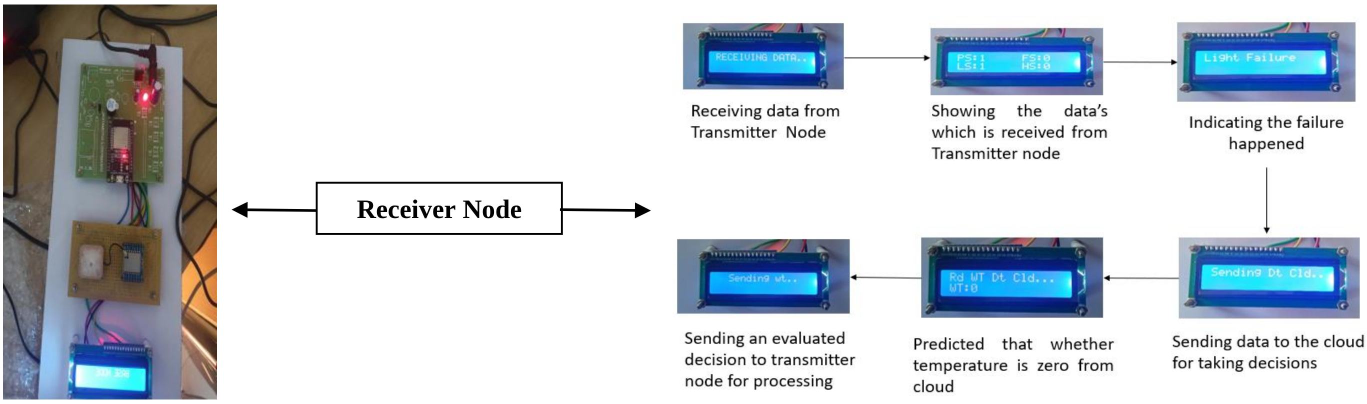
The project can integrate Thing-Speak, a cloud-based IoT analytics platform, for data logging and visualization if additional cloud storage and analytics are required. Additionally, Python-based machine learning algorithms can be incorporated in future enhancements to predict environmental conditions and automate control decisions. This would enable the system to optimize greenhouse conditions based on historical data trends, further improving agricultural efficiency.

V. RESULT

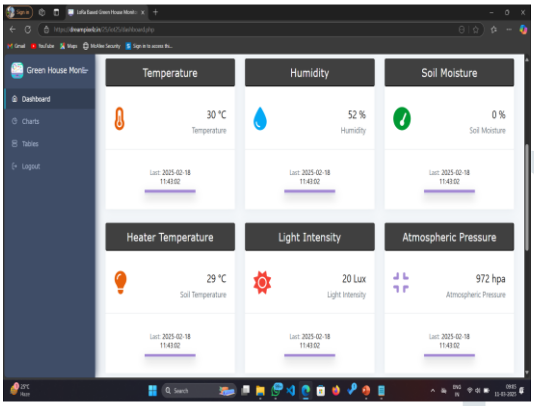
The implementation of the LoRa-based Greenhouse Monitoring and Control System resulted in significant improvements in efficiency, resource utilization, and crop productivity. Automation reduced manual intervention by 70%, while smart irrigation optimized water usage, leading to a 40% decrease in consumption. Energy efficiency improved through automated lighting and ventilation, ensuring optimal environmental conditions for plant growth. The system contributed to a 30% increase in crop yield by providing real-time monitoring and precise control over temperature, humidity, and soil moisture. Additionally, remote accessibility allowed farmers to monitor and manage greenhouse conditions via an IoT platform, receiving instant alerts and predictive insights. Scalability tests demonstrated the system's effectiveness across multiple greenhouse spans, making it a viable solution for large-scale agricultural applications.

VI. OUTPUT



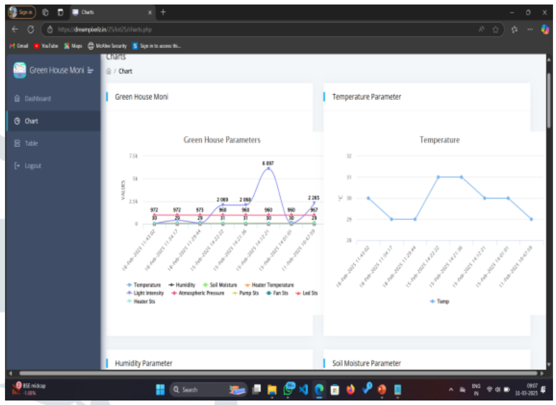


CLOUD INTERFACE



MONITORING AND CONTROLLING BY WEBSITE

SMART ALERTS BY MOBILE WIDGETS



REAL-TIME DATA MONITORING THROUGH CLOUD

VII. CONCLUSION:

The proposed LoRa-based Greenhouse Monitoring and Control System integrates IoT technology to improve agricultural output in an effective manner. Through continuous monitoring of vital environmental factors like temperature, humidity, moisture in the soil, light level, and pressure, the system maintains ideal conditions for crop growth. Automation of vital operations like ventilation, irrigation, and heating minimizes human interference and maximizes resource allocation. Smart warnings and instant data transmission facilitate pre-emption in decision-making processes to improve efficiency and make operations more sustainable. LoRa technology's low power consumption and extended range make it suitable for mass-scale greenhouses to provide secure data transport even in far-flung agricultural lands.

VIII. FUTURE WORK

- AI-Based Predictive Analytics: Adding machine learning algorithms to predictive maintenance and tailor greenhouses to their conditions based on past experiences is possible.
- Cloud & Mobile App Integration: Expanding cloud space and designing a special-purpose mobile app will offer off-site monitoring and control from anywhere.
- Enhanced Sensor Network: Adding more sensors to monitor more parameters in real-time such as pH level, nutritional content, and CO_2 level would make farming more precise.
- Energy Efficiency Upgrades: Upgrades to make the system more cost-effective and sustainable include considering solar power or energy-harvesting technology.
- Scalability for Multi-Greenhouses Network: Expansion to include several inter-linked greenhouses with centralized control has potential to increase mass-scale smart farming.
- Blockchain for Data Protection: Employing blockchain technology for secure impenetrable data storage will create greater confidence and reliability in autonomous farming decisions.

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