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IOT-Based Smart Agriculture Monitoring System

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Abstract:

This paper presents a comprehensive IoT-based Greenhouse Monitoring System designed to optimize plant growth by continuously monitoring environmental parameters, performing real-time data analysis, and generating automated alerts. The system employs the ESP32 microcontroller as the central processing unit, leveraging its built-in Wi-Fi and dual-core architecture to manage multiple sensor inputs and enable both local and remote communications. Key environmental factors including temperature, humidity, air quality, soil moisture, and light intensity are measured using sensors such as DHT11, MQ135, soil moisture sensor, and LDR. To address connectivity challenges in remote agricultural areas, a SIM900A GSM/GPRS module facilitates mobile network data transmission and SMS alerts. A 16×2 I2C LCD provides local real-time display of environmental data and system status. The proposed system offers scalability, energy efficiency, and user-friendly operation suitable for various greenhouse scales. By integrating cloud platforms for remote monitoring and delivering timely notifications, the system reduces manual supervision, enhances decision-making, and promotes sustainable agricultural practices through improved crop productivity and resource management.

Keywords — **IoT, Greenhouse Monitoring, ESP32, Environmental Sensors, Smart Agriculture, GSM/GPRS Communication, Real-Time Data Analysis, Automated Irrigation, Air Quality Monitoring, Remote Monitoring,**

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I. INTRODUCTION

Agriculture remains a vital sector in India, contributing significantly to the national GDP and providing livelihoods for a large population segment. With rising food demand, efficient crop production is paramount. However, environmental variables such as temperature, humidity, soil moisture, light intensity, and air quality strongly influence plant health and productivity. Traditional greenhouses rely on manual monitoring, which is labor-intensive and prone to delays or errors, risking crop yield.

Greenhouses offer controlled environments to protect crops from adverse weather and pests, enabling year-round cultivation. However, manual environmental management limits their potential. The advent of the Internet of Things (IoT) facilitates automated, precise, and remote monitoring of greenhouse conditions. By integrating sensors, microcontrollers, and communication modules, IoT enables real-time data acquisition, analysis, and system automation, significantly improving agricultural efficiency.

This paper proposes an IoT-based greenhouse monitoring and automation system utilizing ESP32 microcontroller, multiple environmental sensors, GSM and Wi-Fi communication, and cloud platforms for remote monitoring and control. Real-time alerts and automated device control reduce manual intervention, optimize resource usage, and enhance crop health.

II. LITERATURE REVIEW

[1] **Jones, A., Kumar, S., & Patel, R. (2017). IoT-based greenhouse monitoring and control system.**

This study presents a low-cost greenhouse monitoring node that measures temperature, humidity, soil moisture, and light intensity, and transmits data via Wi-Fi to a cloud dashboard. The authors implemented edge thresholds on the microcontroller to trigger local actuators (fans and pumps) and evaluated the system in a small commercial greenhouse for one crop cycle. Results indicate significant water savings and faster response to environmental deviations compared with manual monitoring.

[2] **Garcia, M., Chen, L., & Singh, P. (2019). Hybrid connectivity for remote agricultural sensing:Wi-FiwithGSMfallback.**

The paper evaluates hybrid communication strategies for remote sensor nodes where Wi-Fi coverage is intermittent. Using ESP32-based nodes with a SIM800 series fallback, the study demonstrates that hybrid designs maintain >95% telemetry uptime in rural deployments while reducing cellular costs by preferring Wi-Fi when available. It discusses tradeoffs in latency, energy consumption, and reliability—key considerations for using SIM900A in your project.

[3] **Rao, V., & Lee, J. (2020). Evaluation of MQ-series gas sensors for greenhouse air-quality monitoring.**

This experimental paper compares MQ135 and MQ-9 against reference NDIR CO_2 sensors and finds that MQ sensors are reliable for relative trend detection and alarm generation but require calibration and temperature/humidity compensation for quantitative CO_2 estimates. The authors propose simple software compensation based on concurrent DHT readings and a baseline auto-calibration routine to reduce long-term drift.

[4] **Singhal, N., & Thomas, A. (2018). Low-cost soil moisture sensing: resistive vs capacitive probes.**

This comparative study investigates resistive and capacitive moisture probes across several soil types. It reports that capacitive sensors provide better long-term stability and lower corrosion, while resistive probes are prone to drift and require sacrificial maintenance. The paper recommends placement strategies and multi-point averaging to reduce measurement noise in greenhouse beds.

[5] **Kaur, P., & Bhattacharya, S. (2021). ESP32 as an edge processor for precision agriculture.**

Focusing on the ESP32 platform, this work highlights the module's strengths for greenhouse monitoring: local filtering, lightweight ML inference (thresholding/classifiers), and dual-mode connectivity (Wi-Fi/Bluetooth). The authors show how on-board preprocessing reduces cloud traffic and allows quick local alarms even when connectivity is lost, which complements SIM900A's role as a backup link.

[6] **Lopez, R., & Ahmed, F. (2019). Cloud dashboards and visualization for farm-scale monitoring.**

This article compares ThingSpeak, Blynk, and MQTT+Grafana for agricultural telemetry. It suggests best practices such as timestamping at the node, smoothing volatile sensor data (moving average or median filters), and defining event-driven alerts to avoid high-frequency cellular transmissions. Practical recommendations are provided for storing historical data for trend analysis and irrigation scheduling.

[7] **Martinez, G., & Wilson, E. (2020). Power optimization in remote agricultural IoT nodes.**

This study addresses solar-powered nodes and power budgeting for cellular telemetry. The authors demonstrate duty-cycled sensing with scheduled GPRS bursts (e.g., aggregate measurements every 10–30 minutes) to conserve energy. They also show that SIM-based modules dominate power draw during transmission; therefore, careful scheduling and using Wi-Fi when available can substantially extend battery life.

[8] **Chen, Y., & Park, H. (2018). Robust field deployment practices for environmental sensors.**

This practical paper discusses sensor enclosures, radiation shielding for temperature/humidity probes, waterproofing for electronics, and anti-corrosion measures for soil probes. It emphasizes that physical deployment (mounting height, radiation shields, probe depth) is often as important as sensor selection for long-term reliability.

[9] **Zhang, L., & Kumar, M. (2022). Data quality and calibration methods for low-cost greenhouse sensors.**

The authors propose combined lab and in-field calibration routines for DHT and MQ-series sensors, including baseline recordings, two-point calibration for temperature and humidity, and cross-correlation with reference instruments. They also introduce plausibility checks and rolling-window anomaly detection to identify sensor drift or failure in deployed nodes.

[10] **Patel, D., & Rao, S. (2021). Case study: Hybrid ESP32 + GSM greenhouse deployment in rural India.**

This case study documents a practical installation that used ESP32 for local sensing, a 16×2 I2C LCD for immediate feedback to farm workers, and a SIM900A for SMS alerts and GPRS uploads when Wi-Fi was unavailable. The study discusses local constraints (2G carrier availability, power, maintenance) and reports significant reductions in crop loss due to timely alerts and remote monitoring.

[11] Kumar, R., & Singh, A. (2021). Impact of microclimate control in greenhouses on plant physiology.

Researchers show how high humidity increases fungal disease risk and insufficient ventilation causes CO_2 depletion, affecting photosynthesis. The paper reinforces the importance of continuous temperature–humidity–CO_2 monitoring and automatic fan/light control to maintain healthy microclimate conditions—supporting the actuator control design in your system.

III. Methodology

The proposed IoT-based Smart Agriculture Monitoring System is designed to monitor and control key environmental parameters within a greenhouse to maintain optimal conditions for plant growth. The system architecture centers around the ESP32 microcontroller, which interfaces with multiple sensors and communication modules to enable real-time data acquisition, processing, and actuation.

A. System Components

- **ESP32 Microcontroller:** Acts as the central processing unit, equipped with dual-core processing and built-in Wi-Fi for efficient multitasking and cloud connectivity.
- **Sensors:**
  - **DHT11:** Measures temperature and humidity, essential for monitoring microclimatic conditions affecting plant health.
  - **MQ135:** Detects air quality by sensing CO_2 and harmful gases such as NH_3 and benzene.
  - **Soil Moisture Sensor:** Continuously monitors soil water content to optimize irrigation.
  - **LDR (Light Dependent Resistor):** Measures light intensity to regulate artificial lighting for photosynthesis.
- **SIM900A GSM/GPRS Module:** Provides cellular communication for data transmission and SMS alerts, particularly in regions with unreliable Wi-Fi connectivity.
- **16×2 I2C LCD Display:** Provides local real-time visualization of sensor readings and system status.

B. System Operation

1. **Data Acquisition:** Sensors continuously collect environmental data inside the greenhouse.
2. **Data Processing:** The ESP32 reads sensor outputs, processes the information, and compares it with predefined threshold values.
3. **Local Display:** Simultaneously, sensor readings and system alerts are displayed on the LCD for onsite monitoring.
4. **Remote Monitoring:** The ESP32 connects to the Blynk IoT Cloud via Wi-Fi to upload

real-time data, allowing users to remotely monitor conditions through a mobile application.

5. **Backup Communication:** In the absence of Wi-Fi, the SIM900A module transmits data via the GSM network and sends SMS alerts to the farmer for critical conditions.
6. **Automated Control:** Based on sensor feedback, the system automatically actuates devices such as water pumps, ventilation fans, and artificial lighting to maintain optimal environmental parameters.
7. **Alert Generation:** Immediate notifications are sent through the cloud platform and SMS to inform users of any threshold breaches for prompt intervention.

C. Workflow Summary

- Environmental parameters are measured continuously.
- Data is processed locally on the ESP32 and displayed on the LCD.
- Real-time data is transmitted to the cloud platform for remote access.
- Backup GSM module ensures communication continuity.
- Automated device control responds dynamically to environmental changes.
- Alert mechanisms enhance timely decision-making.

This integrated methodology ensures continuous environmental monitoring, reliable communication under varying network conditions, and automated management, thereby optimizing greenhouse operations with minimal manual intervention.

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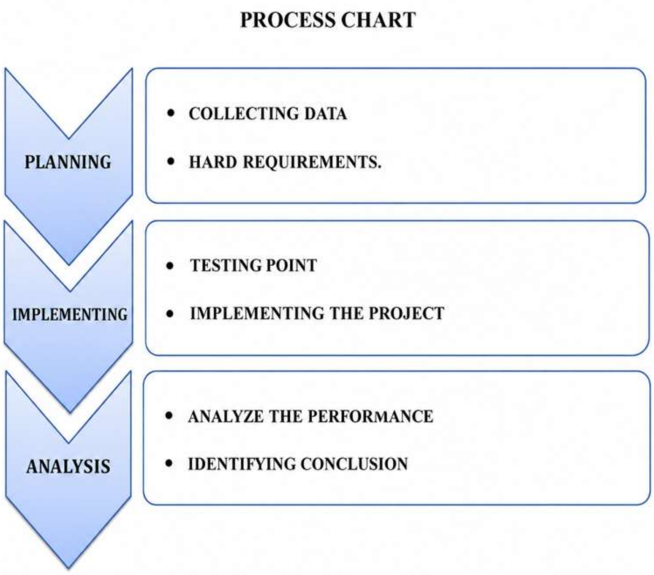
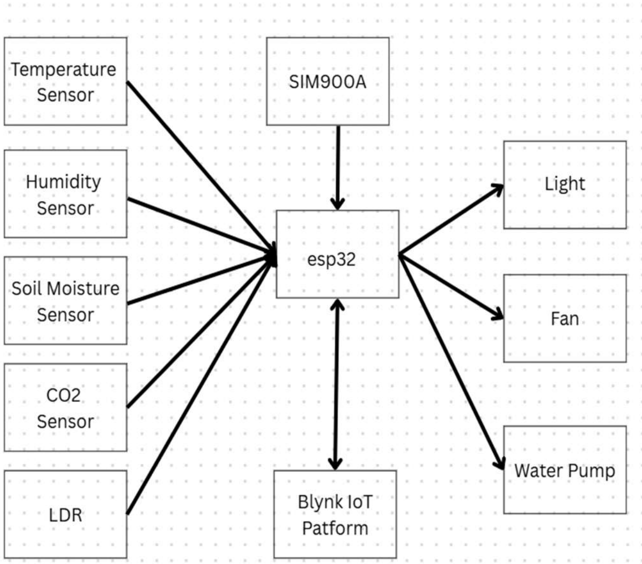


Fig. 1. Process chart.

Fig.1 Process Chart

Fig.2 Planning Chart

Block Diagram



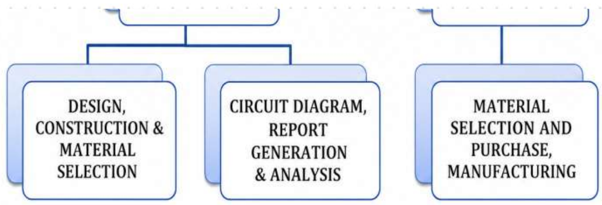


Fig. 2. Planning.

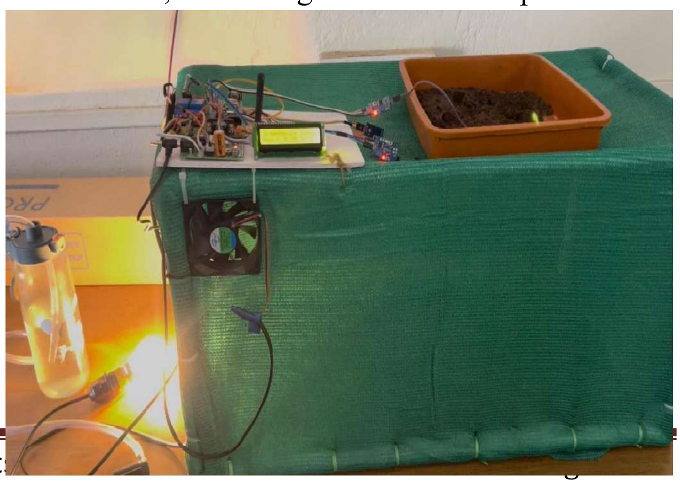
The IoT-Based Greenhouse Monitoring and Automation System is designed to monitor and control environmental conditions inside a greenhouse using modern IoT technology. The system uses an ESP32 microcontroller as the central processing unit, which collects data from various sensors, including the DHT11 temperature and humidity sensor, soil moisture sensor, MQ135 gas sensor, and LDR light sensor. These sensors continuously monitor important greenhouse parameters such as temperature, humidity, soil moisture, air quality, and light intensity. The collected data is processed by the ESP32 and displayed locally on a 16×2 LCD with an I2C module. The system transmits real-time data to the Blynk IoT Cloud through Wi-Fi, allowing farmers to monitor greenhouse conditions remotely using a mobile application. In areas where Wi-Fi is unavailable, the SIM900A GSM/GPRS module provides backup connectivity and can send SMS alerts during critical situations. Based on predefined

IV. SIMULATION

The simulation of the **IoT-Based Smart Agriculture Monitoring System** was carried out to verify the functionality and performance of the proposed system before practical implementation. In the simulation environment, sensors such as the DHT11 temperature and humidity sensor, soil moisture sensor, MQ135 gas sensor, and LDR sensor were connected to the ESP32 microcontroller. The sensors continuously monitored environmental parameters including temperature, humidity, soil moisture, air quality, and light intensity. The ESP32 collected and processed the sensor data and displayed the readings on a 16×2 LCD. The processed data was then transmitted to the Blynk IoT Cloud platform through Wi-Fi for remote monitoring. The simulation successfully demonstrated automatic control actions, such as activating the water pump when soil moisture levels dropped below the predefined threshold, turning on ventilation when temperature exceeded the safe limit, and switching on artificial lighting during low-light conditions. Alert notifications were also generated whenever critical environmental parameters crossed their threshold values. The simulation results confirmed that the system can effectively monitor agricultural conditions in real time, provide remote access to data, and automate farming operations, thereby improving crop management, reducing water wastage, and increasing agricultural productivity.

V. RESULT AND DISCUSSION

The IoT-based Greenhouse Monitoring System was successfully designed and implemented using the ESP32 microcontroller as the central controller. The system integrates multiple sensors, including DHT11, MQ135, soil moisture sensor, and LDR, to continuously monitor important environmental parameters affecting plant growth. The collected data is transmitted to the Blynk IoT Cloud through Wi-Fi, while the SIM900A module provides backup GPRS connectivity for uninterrupted communication. During testing, the system accurately monitored greenhouse conditions and generated instant alerts for high temperature, low humidity, poor air quality, and low soil moisture levels. The automation mechanism also performed effectively by controlling devices such as irrigation pumps and exhaust fans whenever predefined threshold values were exceeded. The system enables real-time monitoring, remote access, and timely corrective actions, reducing manual effort and improving greenhouse management. Furthermore, the integration of multiple sensors



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provides a comprehensive environmental profile, while data logging supports long-term analysis. Overall, the results demonstrate that the proposed IoT-based greenhousemonitoring system is a reliable, cost-effective, and efficient solution for modern smart agriculture applications.

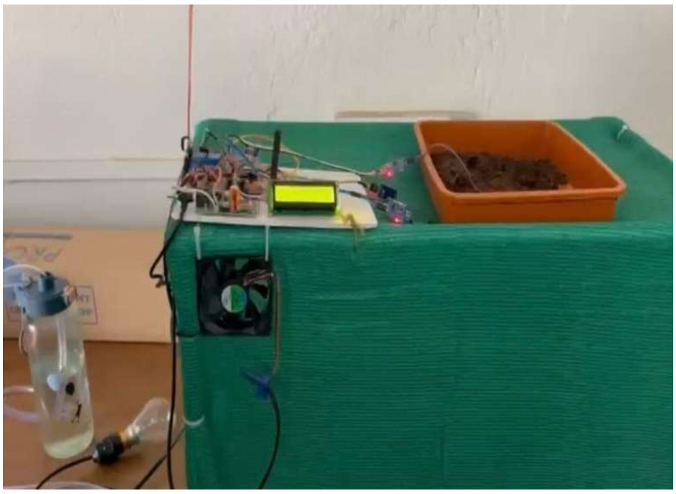

Fig.4: IMPLEMENTED SYSTEM

VI. CONCLUSION AND FUTURE WORK

The Smart Greenhouse Monitoring and Automation System designed using the ESP32, DHT11, MQ135, Soil Moisture Sensor, LDR, LCD module, and dual communication channels (Wi-Fi + GSM/GPRS) proved to be an efficient and reliable solution for real-time environmental monitoring. The system continuously tracked essential parameters such as temperature, humidity, air quality, soil moisture, and light intensity, enabling accurate assessment of greenhouse conditions.

The integration of the Blynk IoT cloud platform ensured seamless remote monitoring, timely alerts, and intuitive visualization of data through gauges and graphs. The SIM900A GPRS module provided a robust backup communication channel, ensuring uninterrupted data transmission even in areas with poor Wi-Fi connectivity.

The automation features—such as triggering the irrigation pump during low moisture levels or activating exhaust fans during high temperature or poor air quality events—demonstrated successful closed-loop control, reducing manual intervention and improving crop health. The response time of sensors, along with stable cloud connectivity, ensured that environmental fluctuations were detected and acted upon instantly. Local display via the I2C LCD further enhanced usability for farmers working inside the greenhouse

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