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Smart Green House IoT Framework for Sustainable Agriculture

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Abstract: ***One notable application of the Internet of Things (IoT) is greenhouse farming, which has revolutionized agriculture by bringing conventional methods into a new era of intelligent, technologically driven solutions. Food shortages brought on by rapid population expansion, climate change, and environmental pollution can be addressed sustainably with IoT-based greenhouses, which automate vital processes like plant monitoring, climate control, irrigation, and resource management. An IoT-based network framework for greenhouse farming optimization is proposed in this paper, which also provides a thorough analysis of IoT devices, sensors, applications, and communication protocols. In order to increase productivity, it looks at smart farming methods, mobile-based greenhouse management, and the fusion of edge and cloud computing. Future approaches for addressing these obstacles are provided by the research, which also examines difficulties like resource allocation, system integration, and security concerns. The study also provides statistical analyses from top agricultural countries and showcases worldwide success stories to set standards for IoT-enabled greenhouse farming. In addition, it presents platforms, topologies, and network architectures; it also presents a taxonomy for farm administration and possible security risks. This effort supports the standardization and worldwide acceptance of IoT-based greenhouses by tackling unresolved problems and promoting sustainable practices, providing a roadmap for more intelligent and effective agriculture.***

Keywords: ***IoT-based greenhouse farming, Smart agriculture solutions, Automated resource management, Sustainable farming practices, Network frameworks and protocol***

I. INTRODUCTION

There is a greater need for efficient and sustainable food production techniques due to factors including industrialization, environmental changes, population growth, and the loss of arable land. A key answer to these problems is greenhouse farming, which was first used in France and the Netherlands in the 19th century. Advances in IoT and ICT have made traditional greenhouses that relied on manual evaluations into smart greenhouses that can monitor and adjust environmental variables like temperature, humidity, and irrigation with little assistance from humans. IoT-enabled greenhouses collect and manage climate data using wireless sensor networks (WSNs), which address factors like light intensity, weather, and water supply. Even with great advancements in research, more effort is required to examine IoT-based network technologies, applications, communication protocols, and prototypes [1]. Population expansion, industrialization, climate change, and the loss of arable land have all increased the demand for efficient and sustainable food production techniques. To fulfill these demands, traditional greenhouse farming—which was first practiced in France and the Netherlands in the 19th century—is insufficient. Smart greenhouses, made possible by IoT and ICT technologies, provide a game-changing solution by automating the monitoring and management of vital farming parameters like crop health, irrigation, temperature, and humidity. Systems that are supported by the Internet of Things (IoT) that include wireless sensor networks (WSNs) and sophisticated communication protocols offer accurate environmental control, less human labor, and increased productivity. For predictive analysis, real-time decision-making, and early illness detection, recent research emphasizes the integration of artificial intelligence and machine learning in Internet of Things-based greenhouses.

II. LITERATURE REVIEW

Internet of Things in Greenhouse Agriculture: A Survey on Enabling Technologies, Applications, and Protocols [2022]
Muhammad Shoaib Farooq, Adnan Abid, Shamyla Riaz, Mamoun Abu Helou, Falak Sher Khan, and Atif Alvi.
The integration of IoT in greenhouse agriculture is examined in this thorough assessment, which also looks at applications, current research trends, and the difficulties in putting IoT-based solutions into practice. The different enabling technologies and communication protocols that are necessary for creating smart greenhouse systems are also covered.

Greenhouse Automation Using Wireless Sensors and IoT Instruments Integrated with Artificial Intelligence [2021]
Redmond R. Shamshiri, Ibrahim A. Hameed, Kelly R. Thorp, Siva Kumar Balasundram, Sanaz Shafian, Muhammad Sultan, Benjamin Mahns, Saba Samiei, and Mohammad Fatemieh. An overview of distributed wireless node automation procedures in greenhouse settings is given in this study. Using a potent dual-core 32-bit microcontroller with LoRa modulation at 868 MHz, these nodes are specially built. The study shows the connection stability, robustness, and dependability of the deployed IoT hardware and software by presenting example findings from both commercial and research greenhouse operations.

Applications of IoT for Optimized Greenhouse Environment and Resources Management [2022].
Chrysanthos Maraveas, Dimitrios D. Piromalis, Konstantinos G. Arvanitis, Thomas Bartzanas, and Dimitrios Loukatos .
It examines the use of Internet of Things (IoT) technologies in greenhouse agriculture. With an emphasis on improving microclimates for crop production, the study looks at how IoT technologies might improve greenhouse settings and resource management.

Incorporating Artificial Intelligence Technology in Smart Greenhouses: Current State of the Art [2022].
Ahmed E. F. Abdelgawad, Hesham M. El-Bakry, and Rasha El-Fakharany. In addition to analyzing several AI techniques including machine learning and deep learning for boosting agricultural output, the study investigates the application of AI technology to improve smart greenhouse operations. The difficulties, possibilities, and potential paths for using AI into smart greenhouse systems are also highlighted.

IoT Based Smart Greenhouse Framework and Control Strategies for Sustainable Agriculture [2022].
Mohammed A. Ghamri-Doudane, Nabil Mohamed, and Hassan Abolhasan. In order to build a smart greenhouse framework, this study investigates how Internet of Things (IoT) technology can be used into greenhouse farming. It talks about a number of IoT-based control techniques for sustainable agriculture, such as tracking and managing environmental factors to maximize resource utilization, boost agricultural yields, and save labor expenses. Along with offering suggestions for future advancements in smart greenhouse operations, the report also examines the difficulties of putting such systems into place.

iGrow: A Smart Agriculture Solution to Autonomous Greenhouse Control [2020].
Tarek S. S. S. Z. A. Taha, Mohamed S. M. Sajid, Mohamed A. M. R. Khalil, Rania Kora, and Dany K. ElBakry. The smart agriculture solution "iGrow," which is intended to automate greenhouse control systems, is presented in this paper. The goal of the project is to increase greenhouse farming's efficiency by integrating autonomous systems and Internet of Things (IoT) technology. The authors examine the iGrow system's architecture, its uses for environmental variable monitoring, and the application of intelligent algorithms to regulate temperature, humidity, and watering, among other things. The system's ability to increase production while consuming fewer resources is highlighted in the article.

III. METHODOLOGY

The Smart Greenhouse framework, which is based on the Internet of Things, emphasizes the integration of advanced technology to improve agricultural productivity while maintaining sustainability. In order to monitor vital environmental factors including temperature, soil moisture, humidity, light intensity, and pH levels, the system starts with the installation of a number of sensors. These sensors gather data in real time, which is then sent via communication protocols like Zigbee, LoRa, and MQTT to a cloud platform or centralized data processing unit. Machine learning algorithms and sophisticated analytics tools evaluate and analyze the data after it has been gathered in order to identify trends, forecast outcomes, and recommend control measures. Once this data has been processed, automated systems use it to handle greenhouse functions like lighting, climate control, and irrigation.Greenhouse operators may access critical information on their mobile devices thanks to cloud-based technologies that provide remote administration and real-time monitoring. A feedback loop is also integrated into the system, enabling ongoing optimization using predictive analytics and real-time data.
Sensor Deployment: Sensors for temperature, pH, light, humidity, and soil moisture track environmental variables.
Collection and Transmission of Data: Zigbee, LoRa, or Wi-Fi are used to transmit data to a local server or cloud platform.
Data Processing & Analysis: Machine learning algorithms and advanced data analytics process data to make decisions.
Controlled by Automation: To maximize plant development, the system manages lighting, climate, and irrigation automatically.
For greenhouse operators, cloud integration offers remote management, historical data tracking, and real-time monitoring.

Feedback Loop: To optimize future operations, the system learns from historical conditions and modifies operations based on real-time data.
Resource Efficiency: The system makes the best use of available resources, including energy, water, and nutrients.
By combining sensors, data analytics, and cloud computing, the framework makes real-time monitoring and decision-making easier. By assessing environmental conditions and using machine learning to forecast future requirements, IoT-based smart greenhouses allow for continual optimization.
Advanced technologies are integrated into the IoT-based Smart Greenhouse framework to maximize agricultural practices for sustainability. Important environmental parameters like temperature, soil moisture, humidity, light intensity, and pH levels are continuously monitored by sensors placed throughout the greenhouse. Cloud systems receive this real-time data using communication protocols including MQTT, LoRa, and Zigbee. To identify trends and offer practical insights for managing lighting, climate, and irrigation systems, machine learning and data analytics are used to process this data. Through mobile devices, greenhouse operators may remotely monitor and manage operations thanks to the cloud-based technology. Water, energy, and nutrient usage are decreased by the system's constant data analysis and feedback, which guarantees resource efficiency and ideal growing circumstances. This clever approach ultimately encourages sustainable farming methods and increases agricultural productivity.

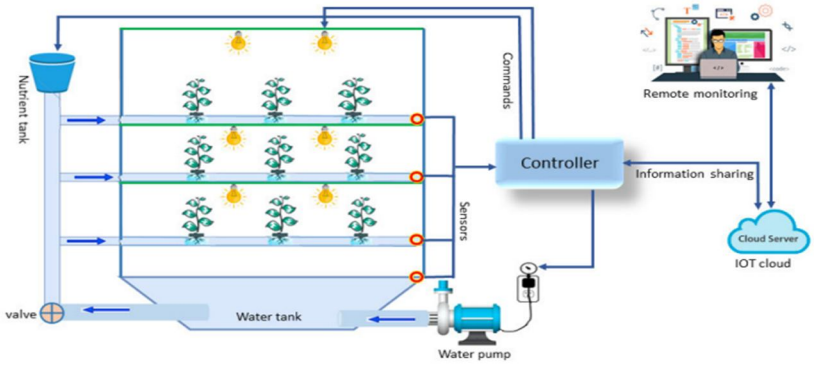


Figure 1-how information is passed.

System flow

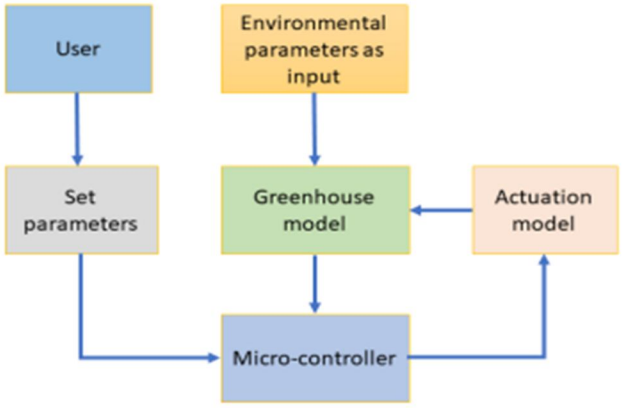


Figure 2-systemflow

In conclusion, there are a lot of benefits to using the IoT-based Smart Greenhouse framework for agriculture in terms of production, sustainability, and resource optimization. Through the integration of sensors, data analytics, cloud platforms, and machine learning, the system allows for real-time monitoring and management of greenhouse operations, minimizing resource consumption and guaranteeing ideal conditions for plant growth. This approach not only improves agricultural productivity but also supports farming practices' overall sustainability.

IV. RESULT AND ANASLYSIS

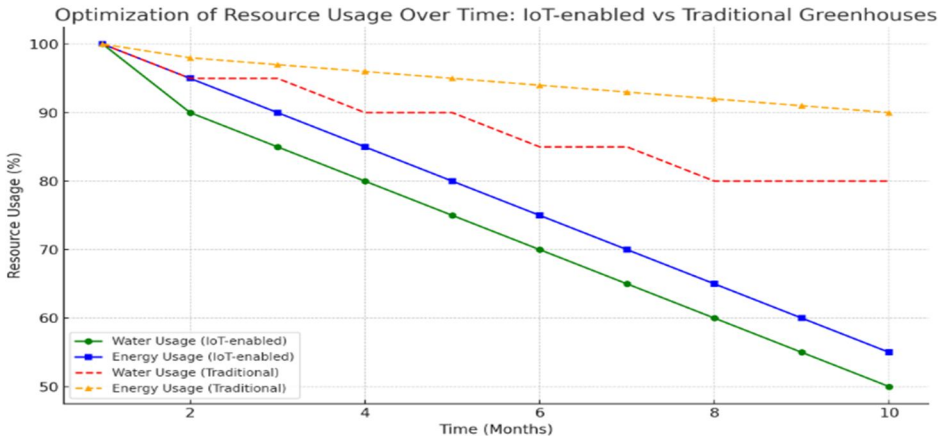
The Smart Greenhouse framework, which is based on the Internet of Things, greatly improves sustainability, resource optimization, and agricultural output. The system guarantees effective use of resources like water, energy, and nutrients by leveraging real-time data from sensors that measure temperature, soil moisture, humidity, light, and pH. Plant growth is maximized and waste is reduced through automated climate, lighting, and watering control. Algorithms for machine learning examine the data to forecast possible problems and gradually improve processes. By precisely controlling the environment and minimizing human error, the method increases crop production in comparison to conventional greenhouses. Cloud-based platform integration enables data-driven decision-making and remote monitoring. This leads to increased effectiveness, reduced expenses, and a less environmental impact. All things considered, the Internet of Things-based smart greenhouse system promotes environmentally friendly farming methods and establishes a new benchmark for effective agriculture activities.

1) The water usage is reduced by 50–70% as compared to conventional greenhouses.
2) Using automatic climate control, energy efficiency reduces energy use by 30–40%.
3) With ideal growing conditions, crop output can be increased by 20–30%.
4) The automated process lowers labor costs by 30 to 50 percent.
5) With early pest and disease detection, the consumption of pesticides can be reduced by up to 40%.
6) By optimizing resource utilization, the carbon footprint can be reduced by 20–30%.

This eventually improves the system's capacity to guarantee ideal growing conditions while consuming the fewest resources possible, increasing the sustainability and efficiency of agriculture.

Technology	Sensor Types	Communication Protocols	Data Processing & Control	Remote Monitoring & Management
IoT-based Smart Greenhouse	Temperature, Soil Moisture, Humidity, Light, Ph Sensor	Zigbee, LoRa, MQTT, Wi-Fi	Machine Learning & Data Analytics	Cloud Integration & Mobile Access
Traditional Greenhouse	Manual Temperature & Moisture Checks	None	Manual Adjustments	Limited Remote Monitoring
AI-enabled Greenhouse	Advanced Sensors, AI-based Vision	High-Speed Internet	AI Models & Neural Networks	Cloud Integration & Mobile Access

The optimization of resource utilization (such as water and energy) over time in IoT-enabled smart greenhouses versus conventional techniques can be displayed in a graph.



V. CONCLUSION

To sum up, the Smart Greenhouse framework, which is based on the Internet of Things, provides a revolutionary approach to contemporary agriculture by maximizing resource utilization, enhancing output, and encouraging sustainability. Through the integration of sensors, data analytics, and cloud technologies, it offers automated control and real-time monitoring of important environmental parameters. This increases agricultural yields, lowers operating costs, and makes efficient use of water, energy, and nutrients. Crop productivity and health are further improved by the system's capacity for problem prediction and prevention. In contrast to conventional greenhouses, Internet of Things-based technologies offer a more reliable, effective, and environmentally responsible method. Intelligent farming has reached a new level thanks to IoT-powered greenhouses as agriculture shifts to more sustainable methods. In addition to helping farmers, this framework also lessens the negative environmental effects of farming. After all, it's a significant step toward a more efficient and sustainable agricultural future.

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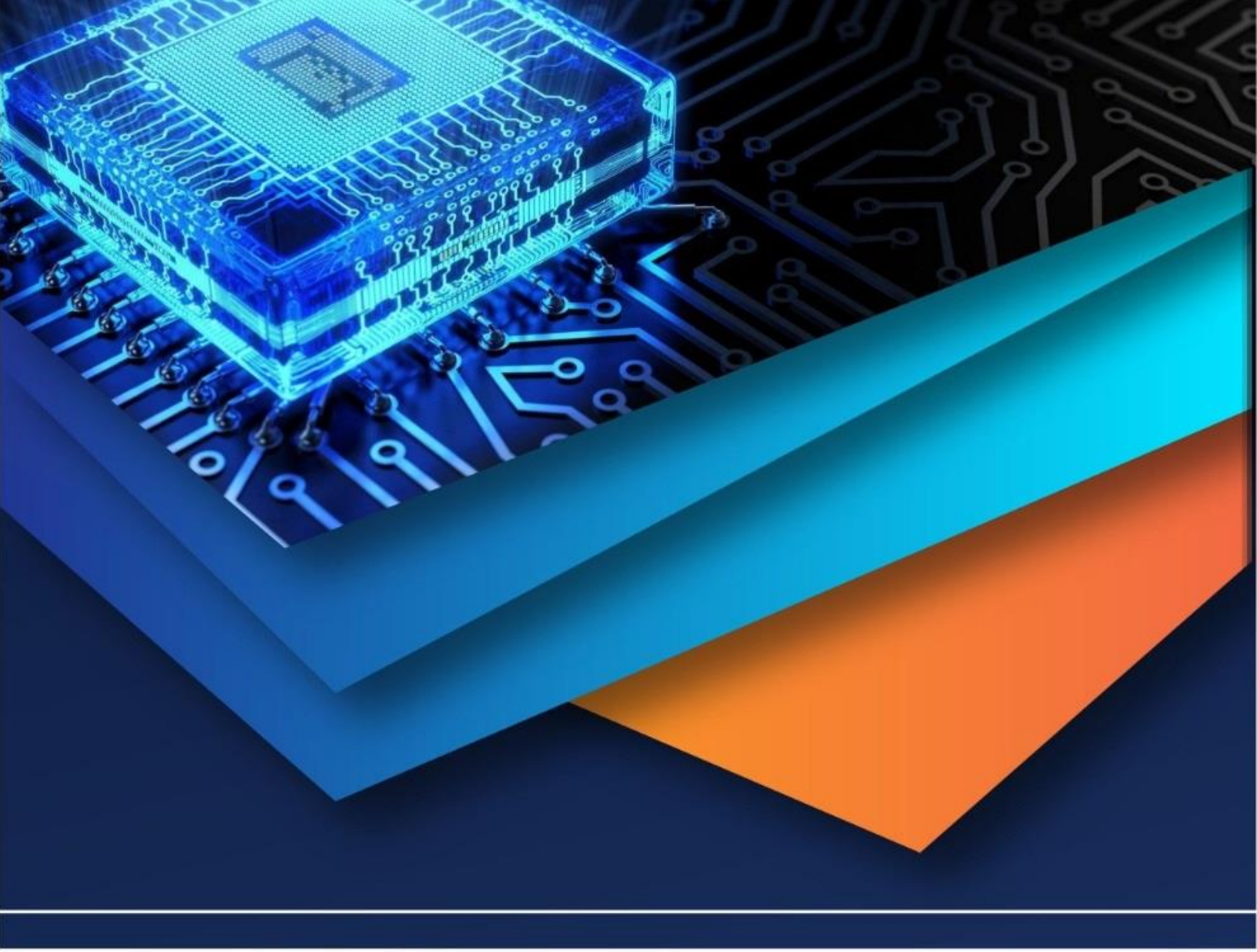

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