Smart Farming: Enhancing Network Infrastructure for Agricultural Sustainability

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Abstract

In addressing the critical challenge of feeding an ever-expanding global population, smart farming emerges as a beacon of hope, despite encountering ongoing issues such as farmers' resistance to adopting new technologies. The approach involves leveraging cutting-edge technology and IoT devices, including various sensors for farm maintenance and monitoring, even in the absence of farmers, through our website. A persistent challenge arises in updating smart farms, particularly in networking capabilities, as they currently lack the adaptability to 4G or 5G. This also causes problems in monitoring real-time data on crucial parameters such as soil moisture, weather conditions, and the absence of a monitoring system on a farm can lead to inefficiencies in resource management, as well as delayed responses to emergencies, impacting overall productivity and sustainability. To overcome this, the proposed study offers a solution by integrating an ESP32 equipped with 4G LTE connectivity. This will provide farmers with real-time data and insights, ensuring appropriate connectivity and enabling robust, high-speed data transmission for farming practices. Moreover, providing solar panel connectivity for power supply further enhances the sustainability and autonomy of these systems. By harnessing renewable energy sources, the proposed method not only ensures continuous operation but also contributes to reducing the environmental footprint of

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agricultural operations. This innovation holds the potential to revolutionize traditional farming methods, paving the way for a more sustainable and productive agricultural future on a global scale.

Keywords: Rural Connectivity, Real-Time Data, Decision-Making, Sustainability, Agricultural Productivity, Cellular Connectivity, Any SIM Cards, Resource Optimization, Remote Monitoring, Environmental Resilience, Automation, Food Security.

1. Introduction

The depletion of agricultural lands due to factors such as rapid industrialization, expanding habitable zones, and the staggering growth of the human population has raised significant concerns, particularly for nations like India. This situation poses a critical challenge, demanding abundant food production to meet the escalating demand. To address this pressing issue, various contemporary techniques and approaches have been developed, among which smart farming stands out as an innovative solution. Implementing smart farm systems with IoT presents farmers with challenges, including weather forecasting and the prerequisite for technological proficiency. The adoption of IoT-based smart farming introduces hurdles for farmers, encompassing upfront expenses and the demand for a certain level of technological expertise. Smart farming seeks to overcome several longstanding challenges and inefficiencies inherent in traditional agricultural practices. These hurdles include:

1.Digital Divide in Farming: The widespread adoption of smart farming technologies is hindered by the limited access to the internet in rural areas. This digital divide creates barriers to the seamless integration of modern farming practices.

2.Climate’s Impact on Crops: Fluctuating temperatures and unpredictable weather patterns can significantly affect crop health, potentially leading to reduced yields and financial losses for farmers.

3.Pest and Environmental Challenges: Agricultural productivity is threatened by various factors, including wandering animals and birds that cause crop damage and grain loss.

Additionally, the precise management of water levels in rice fields demands intricate and meticulous oversight.

In response to these challenges, an innovative IoT-based smart farming system design is proposed to improve farm management, particularly in rural areas with limited Wi-Fi access. This system integrates various sensors and leverages cellular internet connectivity solutions through SIM cards. Key features of this solution include real-time monitoring, alerting and notification and remote management. In real-time monitoring, data empowers farmers with immediate insights into their farm's status, enabling timely decision making. Where alerting and remote management, system can send alerts and notification to farmers' devices, allowing them to respond promptly to changing conditions or nine threats to their crops. The need for physical presence on the farm, which can be especially challenging for remote and large agricultural operations where remote management enhances efficiency, reduces the time and resources required for on-site visits. Moreover, to make this system even more sustainable and efficient, solar panels are used to power it up. Solar panels harness energy from the sun, so farms can generate their electricity without relying on traditional power sources. This makes the whole setup more eco-friendly and reduces costs in the long run. Through this integrated approach, smart farming offers farmers real-time access to critical farm data, enabling them to optimize operations, minimize resource wastage, and ultimately enhance productivity and sustainability in agriculture.

2. Literature Survey

In this section, we explore the cutting-edge advancements made by other researchers in the field of agriculture. Below, we highlight some of the notable contributions in this area, particularly those that involve the integration of various sensors for enhanced monitoring and management of agricultural processes:

As the author Bhumireddy Poojitha and Nainar Nandini in this paper "Smart Agriculture BasedonIoT" [1] focus on the monitoring of Agriculture fields with Internet of Things sensors. they have proposed an automated IoT and smart agriculture solution. This Internet of-Things based farm monitoring system used wireless sensor networks to collect data from various sensors mounted at various nodes and transmit it through wireless protocol. The temperature sensor, moisture sensor, water level sensor, DC motor, and GPRS module are all part of this smart agriculture using IoT system, which is driven by Arduino. It sends an SMS alert to the phone when the levels are reached.

Dharti Vyas, Amol Borole & Shikha Singh in “Smart Agriculture Monitoring and Data Acquisition System” [2] here, they discuss about field signal monitoring system with wireless sensor network (WSN) which integrates different platform with different communication technology. In this paper, monitoring agriculture field where they have to use different sensors with raspberry pi and Arduino or LPC 2148 or AVR based microcontroller. These monitoring data can be observed on webpage or android device.

In the “Environmental Smart Agriculture Monitoring System using IoT” [3] in 2017 authored state the importance of the soilless agricultural technique, as expansion of the habitable zones has led to the depletion of agricultural lands and increased food demand. So, to withstand this situation, one of the prominent techniques applied is hydroponics. Further, integrating hydroponics with the IOT technology escalated the yield profoundly by automating the collection of sporadic data of targeted factors for proper nurturing of crop.

The reviewed papers underscore the growing importance of smart agriculture powered by IoT technology. They emphasize the integration of wireless sensor networks, Arduino-driven systems, and IoT technology to monitor and optimize agricultural processes. These innovations demonstrate diverse applications, ranging from field signal monitoring to climate control systems, highlighting the transformative potential of IoT in improving agricultural efficiency and resilience.

3. Proposed Work

Smart farming system is using a variety of sensors and devices to monitor and control different aspects of the farm environment, including soil moisture, air quality, crop health, and livestock movement and health. This data is being used to automate tasks such as irrigation, fertilization, pest control, and feeding and milking. Additionally, the system integrates a solar panel system for power supply, seamlessly harnessing renewable energy to ensure uninterrupted operation and enhance sustainability in remote or off-grid agricultural settings. This system is still under development, but it is revolutionizing the agriculture industry by helping farmers to improve crop yields, reduce costs, save time, and reduce their environmental impact. This system is utilizing an Esp-32 4G LTE Module for connectivity and incorporates various sensors and actuators to automate and monitor various aspects as shown in Figure1.

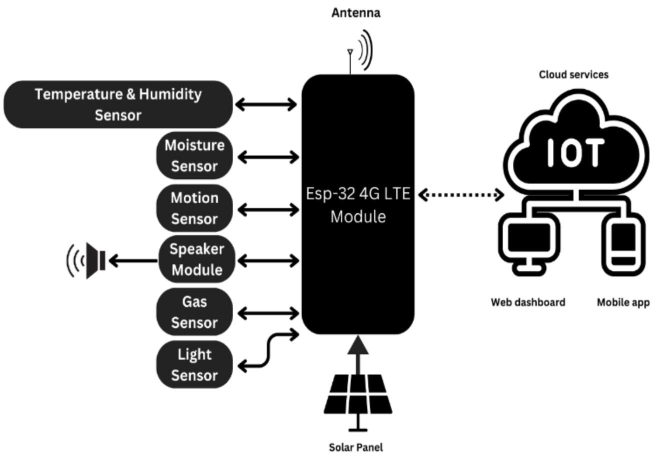

Figure 1. Algorithm implementation for Smart Farming

A. Working

The system outlined in Figure 1, utilizes a range of sensors for monitoring and control. These include a temperature and humidity sensor for climate assessment, a moisture sensor for precise irrigation decisions based on soil water content, a motion sensor for security by detecting movement, and a gas sensor for monitoring air quality. With the Esp32 microcontroller as the central unit, this system processes data from the sensors, acting as the brain that makes decisions based on environmental inputs. The communication modules in the system enable the seam less transmission of data to Firebase, a cloud-based platform, for storage and analysis. Interfacing an ESP32-based system with a built-in SIM card for data transmission to Fire base and present this data through application. This application is integrated with the Firebase Web SDK to interact with the Firebase Realtime Database. In this design, ensuring that the interface can dynamically display and update information in real-time, making it a valuable tool for users to monitor and interact with the data. Integrating sensor data transmission through SMS marks a critical advancement, enhancing data capture capabilities.

B. Sensor Specification

- **DHT11 Sensor:** In Figure 2, the DH sensor is a humidity and temperature sensor designed to measure atmospheric moisture content and temperature in the agricultural environment. This data is crucial for assessing the overall climate conditions, allowing farmers to make informed decisions about irrigation schedules, plant health, and environmental control within green houses. Additionally, DH sensors contribute to the prevention of diseases and pests by providing insights into conditions conducive to their growth. The board includes four pins: VCC, GND, DATA, and NC. It operates on a 3.3-5 volt battery.

Figure 2. DH11 Sensor

- **PIR Sensor:** In Figure 3, the Passive Infrared (PIR) sensor is employed for motion detection, enhancing security and surveillance on the farm. By capturing movement in the designated area, the PIR sensor contributes to both crop protection and livestock management, alerting farmers to any unusual activity or potential threats. PIR sensors also play a role in energy conservation by activating lights or other equipment only when needed.

Figure 3. PIR Sensor

- **Moisture Sensor:** In Figure 4, moisture sensor serves the purpose of determining soil moisture levels, offering real-time insights into the hydration status of the soil. This information is instrumental in optimizing irrigation practices, ensuring that crops receive the appropriate amount of water for optimal growth while avoiding water wastage. Moreover, moisture sensors aid in preventing overwatering, which can lead to root diseases and nutrient leaching.

Figure 4. Moisture Sensor

- **Gas Sensor:** In Figure 5, gas sensor plays a vital role in monitoring air quality on the farm. It detects and measures gas concentrations, providing information about potential hazards or pollutants that may affect both crops and livestock. This capability aids in creating a healthier environment and allows for timely interventions to mitigate any adverse effects. Gas 13 sensors are particularly valuable in preventing the buildup of harmful gases in confined spaces, promoting the well-being of livestock.

Figure 5. Gas Sensor

- **ESP32 4G GSM Module:** In Figure 6, a compact module that seamlessly combines the power of ESP32 and 4G technologies through the SIMCOM A7670C chipset. With support for high-speed wireless communication through 4G LTE, Wi-Fi, and Bluetooth, it ensures swift connectivity for IoT and Industry 4.0 applications. Upgrading legacy devices to 4G enables them to stay relevant in the face of the impending shutdown of 2G/3G networks by network providers. Equipped with the ESP32 dual-core processor and LTE Category 1 module, it offers data transfer speeds of up to 10Mbps, ensuring efficient performance. Additionally, the module supports SMS communication and can connect to the internet using a SIM card data plan, while also providing GPS location functionality. Embrace the future of connectivity with this versatile module, facilitating seamless integration and enhanced capabilities for a wide range of applications.

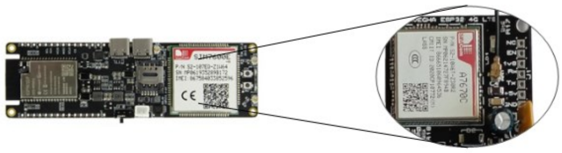

Figure 6. ESP32 4GSM Module

- **Firebase Cloud Messaging:** Firebase is a cloud-based database platform that plays a pivotal role in securely storing and retrieving sensor data in real-time. It facilitates seamless connectivity and data-driven decision-making in smart farming applications. By integrating Firebase, farmers can access and analyze the collected data remotely, enabling them to make informed decisions about crop management, resource allocation, and overall farm optimization. Additionally, Firebase provides a scalable solution, allowing for the expansion of the system as the farm grows and more sensors are added.

4. Result and Discussion

This research involves the development of an advanced agricultural monitoring system aimed at revolutionizing farming practices. We have successful installation of all required libraries and the establishment of fundamental connections. This foundational work has been pivotal in ensuring a robust and stable communication framework between the module and Firebase, facilitating the seamless transmission of sensor data to the cloud. However, as we delved deeper into the intricacies of our research, we encountered a significant hurdle. The integration of a higher number of sensors led to unforeseen delays in the transmission of data to the cloud. Undeterred by this setback, we immediately set about addressing the issue, exploring innovative solutions to optimize efficiency and streamline data transmission processes.

Furthermore, amidst these challenges, our team achieved another milestone by completing the integration of sensors and Firebase with our application. This achievement represents a significant leap forward, as it empowers us to visualize all pertinent parameters on the display screen in real-time, offering farmers invaluable insights for monitoring their farms effectively. Moreover, our system's resilience shines through as it seamlessly provides SMS alerts in emergency situations, ensuring that critical notifications reach stakeholders promptly, even in instances of network connectivity issues. This adaptability underscores our unwavering commitment to delivering a robust and reliable solution that meets the dynamic needs of modern agriculture.

Figure 7. Implantation of the Model in the Farm

The Figure 7, illustrates the implementation of our model on the farm, showcasing the successful integration of sensors including the DH11, PIR sensor, soil moisture sensor, and gas sensor with the ESP32 4G LTE module. This integration has enabled us to collect real-time data on various farm parameters.

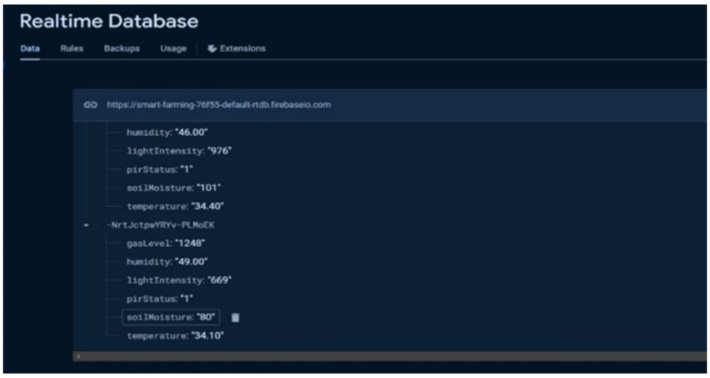

Figure 8. Real-time Dataset on Web Portal

This Figure 8, shows the results of our work. It displays real-time data collected by sensors like the DH11, PIR sensor, soil moisture sensor, and gas sensor. These sensors are connected to the ESP32 4G LTE module, which gathers data continuously. The information from each sensor is then shown on the application interface. This interface is easy for farmers to use, giving them quick access to important information to help them manage their farms better.

Figure 9. Dataset on the Mobile App

In this Figure 9, sensor data from the farm is transmitted to Firebase, a real-time database, through an IoT system. Firebase then serves as the backend for an application, allowing users to access and visualize the data in real-time. The mobile application automatically updates as new data is received, providing farmers with immediate insights into environmental conditions. This enables farmers to make timely decisions regarding irrigation, pest control, and other agricultural practices. By leveraging Firebase's real-time capabilities, the system enhances efficiency and facilitates remote monitoring of farm conditions. Overall, this integration of IoT and Firebase enables effective smart farming by providing seamless access to real-time data.

5. Conclusion

Smart Farming revolutionizes agriculture by using sensors to monitor soil, air, crops, and livestock, improving efficiency and sustainability. Despite its benefits, network connectivity issues in remote areas pose challenges for real-time data transmission, hindering decision-making. To address this challenge, the proposed study has focused on developing an advanced agricultural monitoring system that integrates sensors with the ESP32 4G LTE module. This integration allows for continuous data collection and transmission, even in areas with limited network coverage. Additionally, the system incorporates Firebase Cloud Messaging for secure storage and retrieval of sensor data, enabling farmers to access and analyze information remotely and implementing SMS alerts for farm emergencies is crucial to pre-empt potential consequences. With the successful implementation of the model on the farm, we have demonstrated the potential of Smart Farming to revolutionize agricultural practices and overcome connectivity challenges.

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