Iridium Based Agronomical System

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***Abstract*—IoT-based Agricultural systems are limited by challenges such as unreliable internet connectivity and power supply in remote areas. Featuring the 9603 transceivers, the Iridium-based agronomical system provides a compelling solution for real-time data transmission, remote monitoring, and control of hydroponic systems, irrespective of location. Iridium's satellite network ensures ubiquitous coverage even in the most geographically isolated agricultural plots, making it an ideal choice for global agricultural use. By integrating Iridium-based agronomical solutions, hydroponic farming can thrive in areas where traditional agriculture struggles, promoting sustainable farming practices and enhancing food security and yield productivity.**

***Index Terms*—LEO satellites, Iridium, L-band, compensation, IoT, Agriculture, SBD, AWS, topic**

I. Introduction

The potential for the Internet of Things (IoT) to transform several sectors, with agriculture at the forefront of this transformative wave. IoT technologies can revolutionize farming practices by optimizing resource utilization, enabling precision agriculture, and increasing yields. However, the absence of comprehensive IoT coverage globally remains a significant challenge. This research paper delves into the factors limiting global IoT coverage and explores the impact of this constraint on agricultural IoT applications. It also introduces an innovative solution, the Iridium-based Agronomical System, which can bridge this digital divide and unlock the full potential of IoT in agriculture.

IoT holds tremendous promise in the context of agriculture, empowering farmers to make data-driven decisions, monitor crop health, optimize irrigation, and apply fertilizers precisely. However, the current scenario exhibits stark disparities in IoT coverage, with remote and rural agricultural regions requiring more connectivity infrastructure. This digital divide has far-reaching consequences, hampering the ability of farmers in these areas to harness the benefits of IoT technology.

This research paper illuminated the challenges hindering IoT coverage in agriculture, ranging from the absence of reliable terrestrial networks to issues of affordability and power supply. The tangible impact of limited IoT coverage on agriculture, including missed opportunities for sustainable and efficient farming practices, resource wastage potential, and global food security implications, is examined. At the core of this paper lies the Iridium-based Agronomical System, a technological innovation that has the potential to revolutionize IoT accessibility in agriculture. The low-Earth orbit satellite constellation network of Iridium is utilized by this system, offering global coverage that extends to even the most remote agricultural plots. It promises to empower farmers with reliable and secure connectivity, enabling them to tap into the full potential of IoT-driven precision agriculture, irrespective of their geographic location.

In conclusion, this research paper aims to explain why IoT coverage remains elusive in many agricultural regions and how this limitation affects the agricultural sector. Furthermore, it introduces the Iridium-based Agronomical System as a promising solution that can bridge the digital divide, unlock the transformative power of IoT in agriculture, and foster sustainability and food security in an increasingly interconnected world.

A. Problems and Opportunities

Powered by IoT technologies, precision agriculture can optimize crop management, irrigation, soil health, and resource allocation. However, inconsistent and poor cellular network coverage in many agricultural areas causes significant data delays and loss, impairing decision-making, resource allocation, and sustainability. Bridging this digital divide with comprehensive and reliable cellular coverage for IoT networks in all agricultural regions is crucial for enhancing food production and the economic viability of farming communities worldwide. The agriculture sector must prioritize dependable IoT connectivity to fully harness the transformative potential of IoT technologies.

B. Project Objectives

This project aims to develop an advanced and highly connected data monitoring device specifically designed for precision farming in rural and remote areas. The goal is to create a cutting-edge system matching IoT capabilities while optimizing data transmission efficiency. We have utilized Iridium's 9603 Short Burst Data (SBD) transceivers, known for their power efficiency and impressive bandwidth capabilities, which operate in the L band and are immune to signal loss. Reducing data transmission latency is a crucial objective of our project, imperative for real-time decision-making in precision farming. Our system is built economically and equipped with long-lasting power solutions, making it accessible and viable for smallholder farmers and helping to mitigate concerns

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about energy availability in remote areas. Our innovation aims to bridge the digital divide in agriculture by enabling all farmers to access the tools and insights needed to enhance agricultural productivity, sustainability, and resource utilization, regardless of location or infrastructure limitations. Furthermore, our solution is designed to operate with minimal human intervention, aligning with the trend toward automation and reducing the burden on agricultural workers. Overall, this project is a testament to our commitment to advancing precision farming practices and extending the benefits of cutting-edge technology to even the most remote corners of our agricultural landscape.

II. LITERATURE REVIEW

Smart IoT-Based Greenhouse Hydroponic System is a new technology that integrates IoT technology into hydroponic greenhouse systems to optimize resource utilization, improve environmental sustainability, and increase crop yield. This literature review explores the research on this technology and its impact on various aspects of agriculture. A study in 2023 discussed steps necessary to preserve The greenhouse environment that necessitates meticulous attention to ensure optimal conditions for plant growth that were automated through the application of IoT-based fuzzy-logic in the evaluation process. It demonstrated that the fuzzy-logic controller made the right choices to maintain the ideal Thermal state and humectation levels for fruit production [1].

In 2022, a study was undertaken to explore AutoGrow, a greenhouse system leveraging AI/ML technologies to optimize resource utilization and manage control functions. An IoT system with a wide variety of sensors is used to collect data for AI and ML. In this work, researchers present an Internet of Things (IoT) Employing a data detection and archiving mechanism. Thermal environment, moisture, Hygrometry, pH, and the three major Essential elements (NPK) are only a few characteristics the sub-system can monitor. Additionally, solenoid valves are used as actuators to control the application of irrigation and Soluble in water and fertilizer products [2].

Hydroponics exhibited twice as much production of shoots than base culture. in 2023, according to a comparison of Barley root as well as shoot development in green Internet-connected embedded devices hydroponic cultivation, and platform growing methods. The results were also cross-checked with those from the simulator, demonstrating that the hydroponic cultivation method generated a high-quality, year-round crop with 17112 kilograms of biofuel and 8556 kilograms of dry output [3]. This study automated irrigation by detecting the pH of nutrients with a low-cost sensor; the sensor types employed were pH sensors and wireless nodes. Additionally, this study contrasts conventional agriculture with agriculture already adopting the technology. The Internet of Things (IoT) was used in this study's agricultural applications, which are crucial for enhancing Soil Composition, maximizing water consumption, and Enhancing sustainability [4].

A study by Ruan et al. (2019) categorizes the uses of IoT technology in agriculture into four groups based on the issues they discuss: Planting in monitored conditions in addition to broad fields, animal husbandry., aquaculture, and aquatic farming. It is advised that the emphasis on deploying agriculture IoT systems be broadened Based on the growing phase to the life cycle of Crop yield. The development of green IoT systems will significantly impact farmers' Engagement in IoT technologies throughout the entire Span of agricultural products [5]. In a study by Carlos A. et al. (2022), They develop an extendable IoT-based surveillance system with predictive abilities for implementation in agriculture. This offers a robust Four-layered structure. Economic deployment and management costs comprise sensing, networking, processing, and applications. Therefore, The IoT system under consideration was built, empirically validated, and verified by proctoring the thermic and Moisture states of an Enterprise-level greenhouse in Mexico. It was utilized for six months to prove efficiency.

A Statistically informed forecasting model for greenhouse microclimate Conditions were also encompassed in the proposed IoT system. Within one °C inaccuracy, temperature forecasts made 24 hours in advance were accurate [6]. A study by Chang et al. (2021), To determine the time of harvest and the grade of lettuce grown in a hydroponic system, A novel approach is presented. predict numerous biological variables linked to leaf lettuce plant development (the total number of leaves, border region of leaves, and dry mass), absorption (net rate), and perspiration. Some artificial intelligence methods incorporated include soft computing, neural networks, and a combination of the two. Throughout economic lettuce cultivation in a climate-controlled environment, A compact hydroponic farming system employing the Internet of Things (IoT) was used for gathering Ecological metrics and Mapping systems for gauging and foreseeing plant development characteristics [7].

A study by Namgyel et al. (2018) created an innovative hydroponic system using IoT-enabled LED lighting technologies. Under diverse settings, plants were hydroponically cultivated, and Structural observations were recorded and evaluated. More biomass, leaf density, leaf area, and Chromatic proportion accumulated in the plants exposed to blue supplemental LED light. IoT hardware and software were added to send and show system information online [8]. Andrianto et al. (2020) conducted a study to create Internet of Things (IoT)-based smart greenhouses for hydroponic cultivation. This work also examined the proportion of chlorophyll in mustard leaves cultivated hydroponically in a greenhouse setting to ascertain the mustard plant's nitrogen status. The Arduino Mega2560 serves as the system's controller. The real-time database Firebase stores information on temperature, humidity, Total Dissolved Solids, PH, light, and actuator conditions [9].

III. SYSTEM OVERVIEW

This system is a fusion of Hydroponic System is an innovative fusion of hydroponics systems and the Internet of Things (IoT). Hydroponic systems have become increasingly popular where traditional agricultural methods are not feasible due to limited space, infertile soil, or unfavorable weather conditions. This system can support cultivating various crops, including fruits, vegetables, and herbs. This article outlines the procedural steps for constructing an Iridium based agronomical system:

1. Designing the Greenhouse and Hydroponic System: The initial stage involves carefully designing the greenhouse and hydroponic system, including selecting suitable construction materials, determining the greenhouse and hydroponic system dimensions, and identifying the specific plant varieties to be cultivated.

2. Installing IoT Sensors: After completing the design, it is necessary to install IoT sensors within the greenhouse to Survey critical biological criteria such as temperature, humidity, and other factors that significantly impact plant growth. The sensors are then integrated into a network, enabling the collection and processing of data they generate. The network connectivity options will be with a 9603 SBD modem to connect with Iridium's LEO satellite constellation.

3. Developing a Control System: The next step is to develop a robust control system that harnesses the data obtained from the sensors. This control system is designed to monitor the collected data and make Instantaneous modifications to the conservatory environment. as required. Machine learning algorithms play a vital role in data analysis, providing insights into the optimal growth conditions for plants.

4. Integrating Automation: The system dynamically regulates temperature, humidity, soil moisture content, and water pH. Automation is an essential component. IoT-enabled devices, such as smart thermostats and lighting systems, are utilized for this purpose[11].

Developing a Smart IoT-Based Greenhouse Hydroponic System requires combining technological expertise and horticultural knowledge. With the right resources and tools, creating a system that produces high-quality crops with minimal adverse environmental effects is possible. This system detailed in this study comprises three key segments.

A. Data Acquisition

In the hydroponic system, the greenhouse environment is monitored by several sensors that collect data on various environmental conditions such as temperature, humidity, water quality, and light intensity. The DS18B20 sensor provides additional temperature readings, while the DHT22 sensor measures temperature and humidity. The pH sensor determines the solution's acidity or alkalinity, and the TDS sensor tracks the nutrient concentrations in the water solution. Capacitive soil moisture content sensors capture the moisture proportion in the soil. The collected data is analyzed in real time using an Iridium satellite network, which enables the hydroponic system to maintain optimal conditions for plant growth.

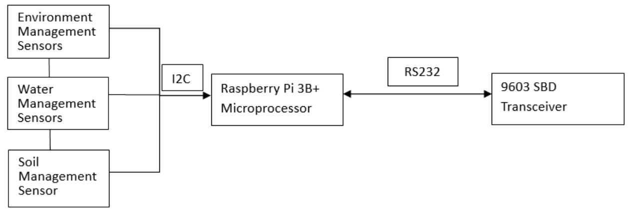

Figure 1. Data Transmission

B. Data Transmission

Based on our previous discussion, we have classified sensors into three categories: environment management, water management, and soil management. The environment management sensors include the DHT 22 temperature and humidity sensors. The water management sensors include the pH sensor, TDS sensor, and Water temperature sensor DS182B0. Lastly, the soil management sensors are capacitive soil moisture sensors. To integrate these sensors, we have utilized the Raspberry Pi 4 B+ 64-bit quad-core ARM Cortex A72 processor, which is equipped with 8GB of RAM and 128 GB ROM and runs at a speed of 1.5 GHz. The processor includes 40 digital GPIO pins, but since no analog input pins are available, we have employed a 16-bit four-channel gain amplifier ADC 1115 to connect the analog sensors to the microprocessor. The microprocessor communicates with the sensors via I2C buses. The output data is transmitted from the microprocessor to the transceiver, which employs RS232 serial communication with a baud rate of 19200 bps. The data is then sent to the Iridium Satellite Constellation as a Mobile Originated (MO) message and received at the ground control. Finally, the system channels the message to the user-specific IP address as a Mobile Terminated (MT) message.

IV. SYSTEM IMPLEMENTATION

To implement a hydroponic system, assembling the hardware as the manufacturer directs is essential. This includes utilizing the Raspberry microprocessor, DHT22 sensor, DS18B20 sensor, TDS sensor, pH sensor, and Soil moisture sensor. The microprocessor settings must be configured with respective interfaces to allow device connectivity. Depending on the surrounding environment, the Raspberry Pi board must be programmed to read sensor data and operate peripherals to maintain suitable and optimal conditions. The system's functionality was written in Python programming language. Calibrating the sensors may require specialized equipment and technical expertise to ensure accurate readings. The system must be tested by monitoring the sensor readings and ensuring it functions as intended. Any issues that arise must be troubleshooted, and the system settings must be adjusted.

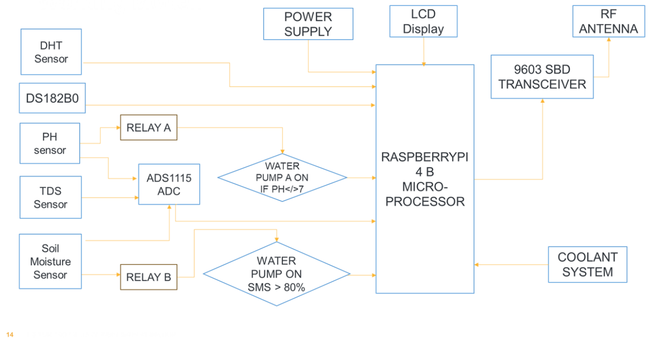

Figure 2. Hardware architecture of the system

Finally, the system should be deployed in the hydroponic environment and continuously monitored for sensor readings.

A. *Field Application Design*

The Iridium Based Agronomical System (IBAS) hardware design consists of the 9603 transceiver as the main component[10]. The transceiver is connected to the Raspberry 4B+ microprocessor using a custom-made serial cable and is used for data sharing and for commanding and controlling the transceiver for the satellite initiation process.A governed 6-volt direct current power source supplies the transceiver. from the power tray, It controls a 6 V supply pulse when provided with a direct current (DC) input that spans 6 V to 30 V. The power plate has an RS-232 serial port, an enable/disable button, and an indication light-emitting diode (LED). while a 5-V DC adapter powers up the Raspberry. The SBD transceiver connects to A fixed-mast helical antenna with an 8-meter coaxial wire, flexible jumper cables, and a lightning/surge limiter for safety. The insertion loss for the cables, connections, and lightning arrestor is tested and does not exceed 3 dB as specified[10].

The IBAS programming component is intended to regulate the data obtained from the sensors and send the most relevant data collected over certain periods of time from the Raspberry to SBD transceivers cost-effectively. The IBAS comprises five conceptual operations:
1. Capture data and buffer write. 2. Apply nonlinear programming methods to maximize the SBD frame.
3. Control and communicate an MO message using a single SBD frame.
4. Retrieve the MT message from IBAS. 5. Verify the current state of the detectors.

The appropriate AT commands are transmitted to the transceiver using the RS-232 interface. During the data-gathering operation, data from all five sensors are accumulated at the microprocessor subframes and Collected throughout the day using the EEPROM memory available on the microprocessor[10]. The system contains an automation unit consisting of DC fans and AC pumps to regulate the ambient conditions of the surroundings. If pH sensors detect any anomalies than

Figure 3. Front View of The IBAS System

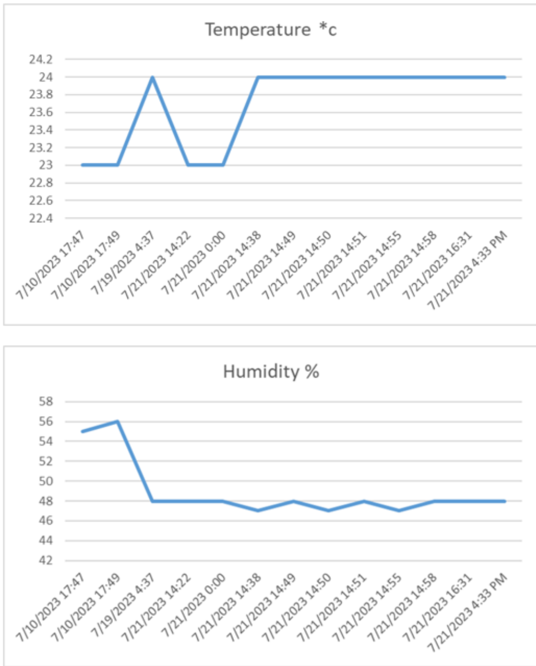

Figure 4. Readings of Environment Management Sensors

the configured values, The pumps are activated to flush the pH balance solution to the main water storage unit, and another pump is activated, and water is drawn out of the central water storage unit if there are any fluctuations in the soil moisture content. The hardware system setup is shown in Figure 2, and the data is sent into the SBD data frame using nonlinear programming. The time interval to transmit the data can vary, but in this paper, we have programmed it to be sent every hour. Additionally, if there are any fluctuations in the data gathered from the sensors, the data will be sent with the status of the corresponding peripherals in the SBD message. The data is transmitted and received from the Iridium satellite constellation in a near line of sight. The overall data and interface can be seen on the LCD, and the whole system setup is shown in Figure 3.

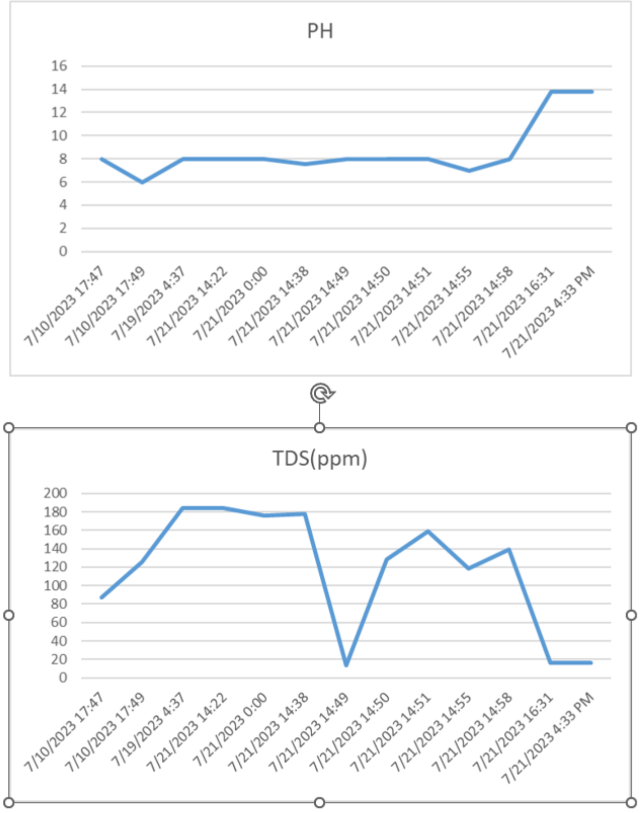

Figure 5. Readings of Water Management Sensors

B. Results and Discussions

In the Iridium's Agronomical system, sensors such as DHT22, DS18B20, TDS, pH, and soil moisture sensors play a crucial role in collecting valuable information about the environmental factors affecting plant growth. These sensors measure temperature, humidity, pH levels, water purity (measured by TDS sensor), water temperature, and soil moisture content, enabling users to make informed decisions to maximize plant growth. Furthermore, the compatibility and mobility of the system allow for easy access to the acquired data, which can be used to plot graphs with corresponding time stamps, as shown in Figure 4. The system's performance aligns with the design specifications and has passed various tests under different conditions. The message Payload is also shown in Figure 5.

V. CONCLUSION

Iridium has been chosen as a viable platform and alternative option for IOT farming due to its global service availability and low hardware and setup costs. Also, the Iridium Network works in the L-band, which is immune to signal loss. A cost-effective agricultural system built with a 9603 SBD Iridium transceiver was developed and tested for MO and MT messages and timing. Further, this can be developed by integrating with Amazon Web Services (AWS) to dynamically store and monitor the data. It can also be plotted and stored in Graffana and other real-time data plotting tools for real-time implications.

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