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IoSIT: An IoT based Cloud Controlled Soil Irrigation Thing for Precision Agriculture

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ABSTRACT:

In the modern arena of smart farming and agriculture, the Internet of Things (IoT) have the potential to act as a game changer by tracking plants' need and soil health. IoT offers a broad variety of applications in the growth of precision agriculture, where the potential of sensor networks and cloud computing assist to address the difficult problems in farming. In this study, utilizing the integrated soil moisture and soil temperature sensors, we construct an ultralow power sensor node. The solution makes it possible to save data in the cloud for later use and to remotely operate an actuator from the cloud as well. Due to the use of MSP430G2553 based hardware, our solution is simpler, affordable, and more energy efficient than existing consumer electronic agro-devices. The actual use of our device – IoSIT is anticipated to result in an economical and energy-efficient sustainable irrigation system.

Keywords: IoT, Precision Agriculture, Soil watering, Cloud Computing, Consumer Electronics.

1. Introduction

Agriculture contributes significantly to the countries' national income and food being a vital source of living deserves an ameliorate, cost-effective technology for production enhancement. Effective use of limited water resources is both a commercial goal and a responsibility to the environment for sustainable agriculture. When it comes to growing crops, humidity and temperature go hand in hand. The need for output in modern agriculture is pressing, and it should be both economical and environmentally beneficial. Plant development is directly influenced by soil temperature; practically all crops grow more slowly at temperatures between 50 and 90 degrees Celsius. In addition to temperature, soil water is particularly important in agriculture since it transports the food ingredients required for plant development. Instead of a lack of other dietary ingredients, the amount of moisture that is available, frequently affects crop productivity. IoT is now a crucial part of creating smart applications in a number of industries, including healthcare, precision agriculture, home monitoring, tree health monitoring etc. [1-4]. Researchers studying precision agriculture have focused on subjects including monitoring fruit growth, soil quality, irrigation, etc. [5-7]. Water is delivered to fields during irrigation by canals, pipelines, sprinkler systems, etc. [8–11]. When there is a lack of rain, irrigation aids in the correct development of crops. Monitoring of the soil water level is necessary for smart irrigation. Determining whether a water supply is required or not is aided by the study of data on soil water levels. Also, it is important to have the right quantity of water supply at the right moment.

1.1 Motivation and Contributions

It has been observed that there are limited IoT-based open platforms, devoted just to precision irrigation for farming. IoT platforms act as a connection point for connected IoT devices' sensors and data networks, enabling them to communicate with each other utilizing Internet transfer protocols. Large amount of data is continually sent to a "data lake", which might be a local physical server or cloud-based storage, from the sensors of the devices in an IoT network. IoT should include everything in large-scale networks where different networks should coexist and be able to communicate with one another via a variety of gateways and middleware with the assistance of a complicated control plane. The Wireless Sensor Network (WSN) is used to gather data in traditional irrigation systems. Nevertheless, the ability for remote access will not be available if just local storage is used. As a result, there is a disadvantage in that the user cannot remotely turn on and off the water supply system.

The five fundamental components of agriculture groundwork—nutrients, water or humidity level, temperature, insecticides, and light—are all interdependent. The basis of the smart agricultural system is data collection, decision-making, and action.

The development of IoT with regard to designs, enabling technologies, and potential difficulties should be considered first in order to have a generic network infrastructure. Many published survey reports from recent years examined IoT technology from various angles. The IoT is used on the cloud side to aggregate the data that are supplied from the gateway on the sensing side. To make sure the incoming telemetry signals are authentic, it also applies various security measures.

The aims of the researchers are:

• Provide farmers and analysts remote access to the data and control over the water supply system's on/off switching.

The researchers' contributions help achieve this goal in the following ways:

• The device collects data on soil temperature and moisture before sending it to the cloud for further analysis. The equipment has a Wi-Fi transceiver that sends the information to the

cloud. Once the soil moisture and soil temperature data collecting take place, soil health monitoring may be accomplished.
• The farmer/analyst uses a portable mobile device to obtain the data. The user then remotely turns on/off the water supply irrigation pump via the cloud depending on the data analysis.

2. Related Work

In agriculture water is very important factor for cultivation, water should be provided in right amount to the plants. Little or too much water can kill the plants. Joaqun Gutiérrez et al. [1] described the development of an automated irrigation system to maximize the usage of water for agricultural crops in their work Several investigations focusing on smart agriculture. The WSN is often used to gather sensor data [12], which is then evaluated in the cloud [13]. In recent years, academics' focus has turned to irrigation, a crucial area of agriculture [8–11]. In [10], the authors suggested an irrigation system based on cloud computing and wireless sensor and actuator networks. Several investigations focusing on smart agriculture. Zirconia sensors were mentioned in [16] for measuring soil moisture content. Plasticide Polyvinyl Chloride (PVC) pipes were employed as a cover for the sensors' construction. In [8], an IoT-based irrigation system was addressed. The authors predicted the daily water need for irrigation using sensor data and a regression algorithm. A wireless communication and supervisory control auto-irrigation system was suggested in [17]. In [18], a different auto-irrigation system was covered using a Raspberry Pi. A prototype approach for regulating auto-irrigation was created in [19]. An auto-irrigation system based on WSN and an embedded Linux board was suggested by the authors in [20]. IoT in agriculture provides decision support systems that help farmers to know the real-time information of their field [21] and Wireless sensor network (WSN) has been used for precision farming throughout the world [22] respectively, focussing on IoT based smart and sustainable agriculture. In [23] and [24], the researchers proposed cloud and genetic algorithm based IoT in precision agriculture.

3. Product Description

The device is designed using ultralow power microcontroller cubed with sensors and ESP01 for Wi-Fi communication. The device is powered using 18650 Li- ion battery. The sensor node collects the data from the field and sends the data to the cloud for analysis. In this section we shall discuss the architecture, design and implementation of IoSIT.

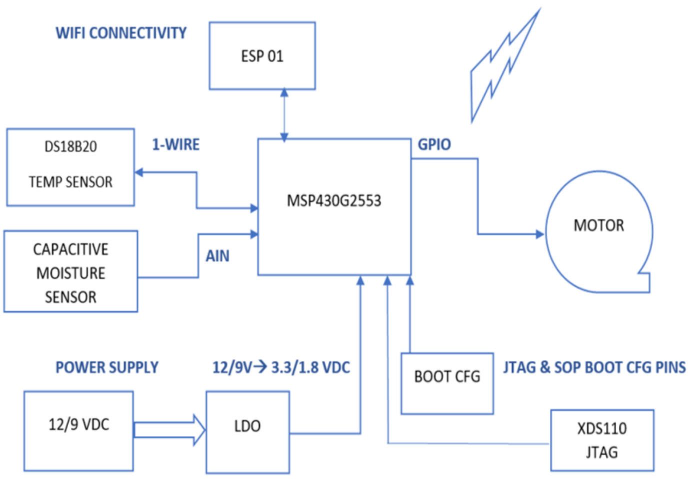

Fig.1. The architecture of the device IoSIT

3.1 Architecture of IoSIT

In the root zone of the plants, a distributed wireless network of soil-moisture and temperature sensors is used in the system. A gateway unit also manages sensor data, activates actuators, and sends data to a web application. To control the amount of water, a microcontroller-based gateway was designed with an algorithm based on temperature and soil moisture threshold values. Photovoltaic panels provided the system's energy, and it had a duplex communication link based on a cellular-Internet interface that allowed users to schedule watering and review data via a web page.

The device is designed in such a way that all the GPIO pins can be utilized for default components.

Sensor and actuator unit: The sensor unit collects data on physical field characteristics and transmits it to flash memory via Serial Peripheral Interface (SPI). The data is subsequently saved and sent to the cloud for storage and analysis by the SPI flash memory. The IoSIT has 27 GPIO pins, which gives you the convenience of connecting several sensors and actuating nodes. Many sensors and actuators that are compatible with different communication protocols, such as I2S Channels, SPI, I2C, and UART, may be interfaced with IoSIT by the user.

Processing unit: While it analyses the real-time data received from the field, the processing unit serves as the device's brain. Memory unit: The device's memory unit is an essential component. The IoSIT's memory portion consists of 256KB of Random Access Memory (RAM), 1MB of optionally executable flash, and serial flash.

Power control unit: This component handles electricity distribution. The node is powered by the system using 18650 rechargeable Li-Ion batteries. The sensors are powered by Low Dropout (LDO) in the system. The sensors may be categorized as an energy-efficient sensor node since they are an ultralow power module. To turn on and off the pump, a 30A Single Pole Double Throw (SPDT) relay included within the device may be operated remotely through the cloud. The farmer's or the analyst's visual display unit may be used to monitor the present state of the pump attached to the sensor node.

Communication unit: The device utilizes an ultralow power MSP430G2553 microcontroller that stores the on-field collected data in the flash memory and send the data to the cloud using WiFi802.11b/g/n station protocol. The Wi-Fi communication is established using ESP01, which is cubed with the microcontroller. Wi-Fi transceiver to send the data to the cloud and receive the ON or OFF instruction from the user via cloud to operate the connected actuator. This user-friendly device is unique in its own way.

3.2 Design of IoSIT

The suggested sensor node's design, the integrated design of the sensors, and the application server are all covered in this part.

Sensors' integrated design: Two separate sensors have been used in this design: a capacitive type soil moisture sensor and a DS18B20 soil temperature sensor. The combined design of the sensors is shown in Fig.2. The sensors are pre-calibrated and embedded with the MSP430G2553 controller using the Inter Integrated Circuit (I2C) protocol to get real-time data from the field where the sensor node is installed. To get the temperature and moisture content of the soil in real time, the sensors are buried 10 cm into the surface. After being saved in the SPI flash for a further 30 minutes, the real-time data is subsequently transferred to the cloud for storage. While the sensor node is in SLEEP mode, the data is retrieved, and when it is in ACTIVE mode, the data is delivered to the cloud. The farmer/analyst has access to the stored data on the cloud. The farmer/analyst regulates the flow of water by running the pump using a web application based on the soil relative moisture and soil temperature information. We may refer to the usage of the web application as a water-saving IoT gadget since it enables effective irrigation pumps for water delivery.

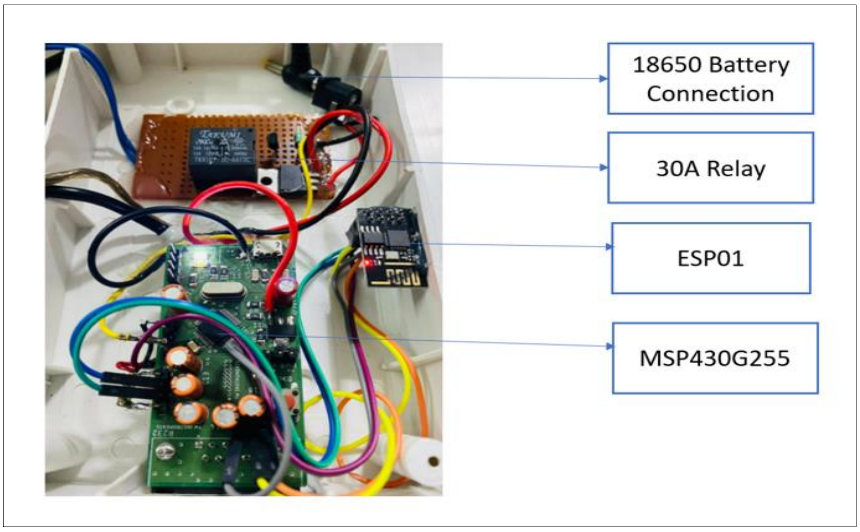

Fig. 2. Wi-Fi based ultra-low power sensor nodes

Application Server: The server uses HTTP and TCP, which function at the application and transport layers, respectively, to receive and transfer data. By transferring information through the Wi-Fi connection to the ESP01, the application server regulates the actuator state either ON or OFF.

3.3 Implementation of IoSIT

We implemented and installed IoSIT in two separate locations of West Bengal, India sites in order to get the real-time data: (i) one was placed at Barasat, North 24 Parganas and (ii) another one was put at Mankar, Burdwan district.

Data collection and storage: The government pump operating station and the crops were both present where the sensor node was placed in the field. We wired the pump with the 30A SPDT relay which is embedded with the controller and the relay can be controlled through the web application. The cloud-stored data were retained for future study and use as a source.

Remote communication: The sensor node has a special function called remote communication that enables users to operate actuators from a distance without sending SMS or physically being close to the field. The user may control the actuator or the pump connected with IoSIT device from any location for watering the field when required. This feature of cloud-controlled device is unique in its own way.

4. Results and Discussion

This section includes a discussion of the experimental design and the findings.

Experimental Setup We installed the sensor in the paddy field for 23 days, after which we

downloaded the data. We managed the pump to deliver water to the paddy field based on the data analysis. In our experiment, we employed the LAMP (Linux, Apache, MySQL, and PHP) stack.
The major lookout for the experiment was irrigation, using the remote server and energy saving: The experiment's server ran on a Linux operating system. The HTTP protocol was used to deliver online content and handle requests on the Apache web server. MySQL was used for database administration. Lastly, PHP was used to create the user interface. TABLE 1 displays the experimental set-up. Figures 1 and 2 show the system architecture and the integrated design of the sensors, respectively.

Table 1: Experimental Setup

Parameter	**Value**
Area of Each Sub field	1 Acre = 61*66 m2
Sensing Interval	1Min
Sending Interval	120Min
Wireless Protocol	Wi-Fi
Sensors used	Soil Temperature and Soil Moisture
Internet Service	Wi-Fi Zone created near pumphouse
Period	6 Month
Crop Season	Aman
Crop Type	Paddy Rice

A snapshot of the web application used by the farmer or analyst to turn on and off the motor in response to data about the soil's temperature and moisture obtained from the cloud is shown in Fig. 3. The actuator is turned ON from a distant location to irrigate the field while the soil moisture and temperature data are being stored in the cloud. As shown in Fig. 3, this causes the soil's moisture content to rise and its temperature to drop.

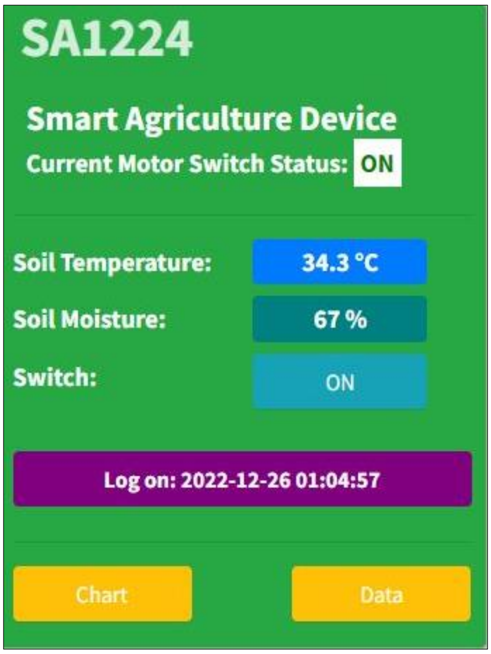

Fig. 3. Snapshot of the web application used to switch on/off the water supply pump

The temperature/moisture log report from the experiment is shown in Fig. 4. Here, we have shown the statistics of three days from the 23 days. In the figure the red dots show the soil temperature and the blue dots represents the soil moisture data respectively received from the field. The variation in the moisture line signifies the gradual increase or decrease of moisture irrespective of the change in soil temperature which in turn indicates the time to switch on/off the pump remotely. Three 18650 Li-ion battery cells, each rated at 3.75V and 5.8Ah, are used in this experiment as power supply to the gadget. Fig.5 represents the same statistical data in tabular form.

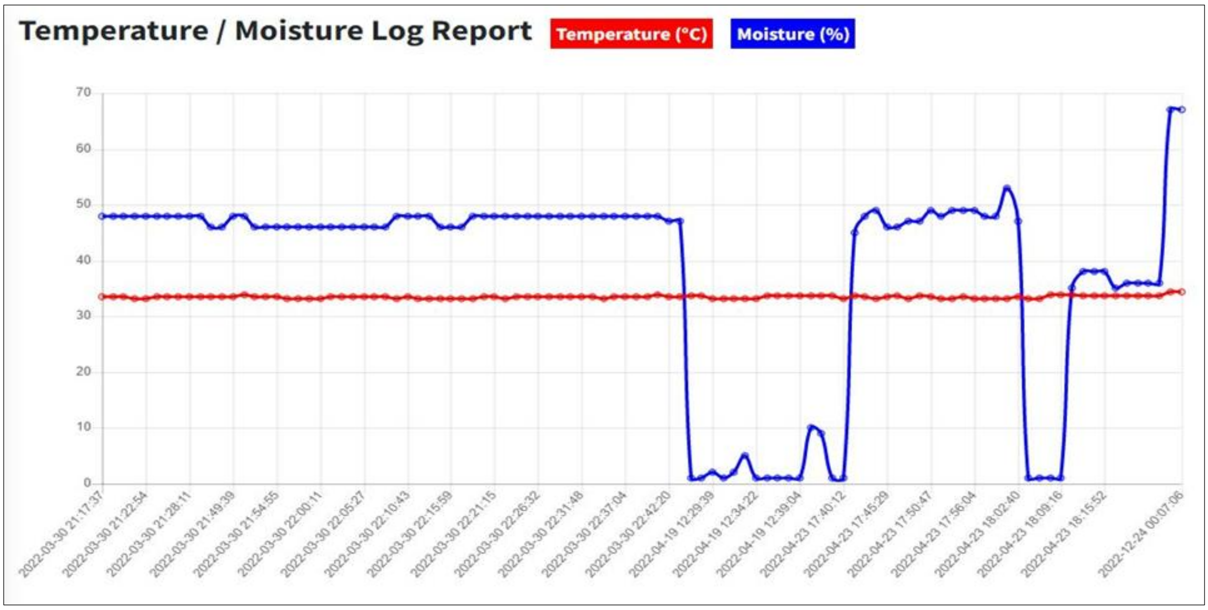

Fig. 4. Temperature/moisture log report graphical representation captured from the cloud

Temperature / Moisture Log Report

Export to Excel Search:

Log#	Device ID	Logged On	Temperature	Moisture
96550	SA1224	2022-03-30 21:17:37	33.5	48
96551	SA1224	2022-03-30 21:18:57	33.5	48
96552	SA1224	2022-03-30 21:20:16	33.5	48
96553	SA1224	2022-03-30 21:21:35	33.1	48
96554	SA1224	2022-03-30 21:22:54	33.1	48
96555	SA1224	2022-03-30 21:24:14	33.5	48
96556	SA1224	2022-03-30 21:25:33	33.5	48
96557	SA1224	2022-03-30 21:26:52	33.5	48

Fig. 5. Temperature /moisture log report table captured from the cloud

We contrast our proposed sensor system (IoSIT) with the current sensor systems in TABLE 2. The suggested system's compatibility with different interfaces is shown in TABLE 2. Our system's General-Purpose Input/ Output (GPIO) pins allow us to connect a variety of sensors and actuation nodes. As the device is connected with ESP01 there is always a possibility of not losing the complete communication with the device as it is not dependent on SOC. With Wi-Fi it reduces the cost of the design where, using an GSM kit or Zigbee may have induced huge cost for the farmers to install.

Table 2. Comparison Table with IoSIT and Other Devices

Sensor Node	**IoSIT**	**MICA2DOT [25]**	**AgriSens [26]**	**Automatic Irrigation Controller [27]**
Processor	MSP430G2553	ATmega128L	ATmega324PA	ATmega32 Nano
Communication Module	ESP01	CC1000 radio transceiver	Zigbee	SIM800
Integrated Sensors	Soil Moisture, Soil Temperature	Temperature and battery monitor	NA	Temperature, pH, Hall, humidity, etc.
GPIO Pins	27	18 solder-less expansion pins	18 solder-less expansion pins	No GPIO pin open for user
Compatible Interfaces	SPI, UART, 12C, ADC.RS485, I2S	UART, SPI, 12C, ADC, Digital	UART, SPI, 12C, ADC, Digital	SPI, UART, 12C, ADC
LDO Present	YES	NO	NO	NO
Cloud Controlled Remote Server	YES	NO	NO	NO
Processor in Bit	16Bit	8Bit	8Bit	8Bit

5. Conclusion and Future Scope

The MSP430G2553 controller, which is connected to ESP01 as Wi-Fi Network Processor integrated with a soil moisture and soil temperature sensor, is used in our current study to show the design, architecture, and implementation of an ultralow power Internet of Things device for soil irrigation. With our system, a farmer or analyst may obtain data on soil temperature and moisture levels stored in the cloud, and use a web application to control the water supply irrigation pump appropriately. The data is kept in the cloud for further examination. Future research in this area may focus on artificial intelligence-based SOC for temperature and moisture sensing in the soil. Future study areas for this endeavor may include the use of blockchain and dew computing, both of which show significant promise.

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