L&M Farm: A Smart Farm based on LoRa & MQTT

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Abstract— Smart farms are the future of Agriculture, which are expected to increase productivity with low-cost and high convenience. Nevertheless, farmers are skeptical of running smart farms, due to their expensiveness, inefficient energy consumption, difficult management, and potential data leakage. Many studies suggest using LoRa (Long Range), a type of LPWAN (long power wide area network) technology, which is capable of long-range with economical price and small battery consumption. However, studies overlook on how to transmit data proficiently, safely and assuredly. Therefore, this study proposes L&M Farm, a LoRa and MQTT (Message Queue Telemetry Transport) based smart farm. MQTT is a lightweight messaging protocol that guarantees the reliability and security of data while minimizing the wastage of packet space. The prototype uses two Arduino Boards with Dragino LoRa Hat, in which one is connected to the VH400 soil moisture sensor and DHT11 temperature and humidity sensor, the other connected to a solenoid valve irrigation actuator. Also, there is a Raspberry Pi irrigation node, which uses Open Weather API to get 5 days of weather data. In addition, a web-based application for farmers to conveniently manage the smart farm.

Index Terms——L&M Farm, Smart Farm, LoRa, MQTT, IoT

I. Introduction

According to the Food and Agriculture Organization of the United Nations, the definition of "Smart Farming is a farming management concept using modern technology to increase the quantity and quality of agricultural products" [1]. Smart farms play a big role in achieving precision agriculture, also known to be the future of agriculture [2]. It monitors soil, irrigation, and weather conditions in order to increase productivity [3].

For example, smart farms collect vital agriculture data using IoT sensor technology [4]. Weather forecast data-gathering is performed using open-source weather API (Application Programming Interface)s, in which Big Data technology is the key foundation [5]. Data analysis of the collected data facilitates the optimization and modification of the surrounding environment [6]. Moreover, it offers predictions of when the crops need water. Deploying a mobile or web-based application that provides this information serves farmers' convenience in management.

Despite many advantages, there are still many obstacles to smart farms yet to overcome. [7] carried out a survey of research activities in smart farming, and pointed out that incentives, investments, innovative tools, data, network, and information are the barriers smart farms must conquer. Five key factors of smart farms are mentioned for the need of consideration: 1) low-cost, 2) energy efficiency, 3) convenience on management, 4) data transmission, 5) assurance of high security and reliability.

Consequently, the decision making of the network technology is crucial. LPWAN (long power wide area network) is a popular wireless communication network technology for IoT applications, due to small power consumption, high coverage, and inexpensive communication features [8]. Sigfox, NB-IoT, and LoRa (Long Range) are the three highly favored technologies of LPWAN. [8] conducted a study to compare the three technologies in different IoT deployments and concluded Sigfox and LoRa are the most appropriate for smart farms.

However, there weren't any studies that focused on messaging protocols for smart farms. The size of the data received from soil moisture, temperature, humidity sensors is very small. Hence, in order to efficiently transmit data, minimizing the wastage of packet space is necessary. In addition, the reliability and security of the data transmission must be guaranteed. There are several IoT communication protocols (e.g. DPWS, XMPP, CoAP), but MQTT (Message Queue Telemetry Transport) is most suitable for IIoT (Industrial IoT) applications [9].

MQTT is an extremely lightweight messaging protocol. As stated in [10], "the design principles of MQTT is to minimize network bandwidth and device resource requirements whilst also attempting to ensure reliability and some degree of assurance of delivery". MQTT has just 4 bytes of fixed header overhead and is the only IoT protocol that has QoS (Quality of Service) options up to 3 levels [9].

Therefore, this study proposes L&M Farm, a smart farm based on LoRa and MQTT which meets the criteria of smart farms mentioned above.

The remainder of the study is organized as follows: Section 2 compares the previous works that have been done on LoRa and MQTT. Section 3 explains the design of L&M Farm. Section 4 explains the result of the implementation. Lastly, Section 6 concludes the paper.

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II. Related Work

A. LoRa

Sarker et al. [11] demonstrated the benefits of applying LoRa technology to IoT. The study concludes that using an integration of cloud and edge computing is more appropriate than only using cloud computing in the LoRa IoT environment because it reduces the waste of resources.

Muangprathub et al. [6] proposed a system to control environmental factors in crop fields. Also, they implemented web application and mobile application, which allowed for automatic and manual control. However, they used only WiFi of the NodeMCU, which has a voltage of 135-215 mA. Our study is using LoRa network to develop a more efficient system in terms of power consumption.

Ko et al. [12] demonstrated through experiments that LoRa was the most efficient among many LPWAN protocols and found the optimal PHY configuration setting on the LoRa network. In addition, they found that the variation of tree farms was bigger than the variation of open area and that the RSSI's variation was more consistent in the tree farm than an open area.

B. LoRa and MQTT

Spinsante et al. [13] proposed a system for building automation services using LoRa and MQTT. This study verified that LoRa suits well in indoor scenarios, and the use of MQTT fulfilled the real-time requirements of the building automation service.

Huang et al. [14] proposed a marine wireless sensor network monitoring system based on LoRa and MQTT. This study proved that even though the sensor packages are in an outdoor water environment, the data from sensors don't affect significantly if the whole set of equipment is within a certain coverage of the wireless signal.

Kodal et al. [15] proposed a smart IoT farm model based on LoRa. Similar to our study, the system uploads data to the cloud using the MQTT protocol, but this system only has the monitoring part.

III. Design of L&M Farm

This work aims to design a smart farm that fulfills all the key factors mentioned in Section 1 and provides convenience in management for farmers by deploying a web-based application.

A. Required Components

TABLE I. Required Sensors

Parameter	**Sensors / Value**
Temperature and Humidity	DHT11
Soil Moisture	VH400
Solenoid Valve	0~0.8MPa
Relay Module	High-level trigger

TABLE II. DHT11 Features

Operating Voltage	3.5V to 5.5V.
Operating current	0.3mA (measuring) 60uA (standby)
Output	Serial data.
Temperature Range	0°C to 50°C.
Humidity Range	20% to 90%
Resolution	Temperature and Humidity both are 16-bit.
Accuracy	±1°C and ±1%

TABLE III. VH400 Features

Power consumption	< 13mA
Supply voltage	3.5V to 20 VDC.
Power on to Output stable	400ms
Output Impedance	10K ohms
Operational temperature	-40ºC to 85ºC
Accuracy at 25°C	2%
Output	0 to 3V related to moisture content
Shell color	Red
Voltage Output Curves	Curves, Piecewise linear equations
Certifications	CE Declaration of Conformity

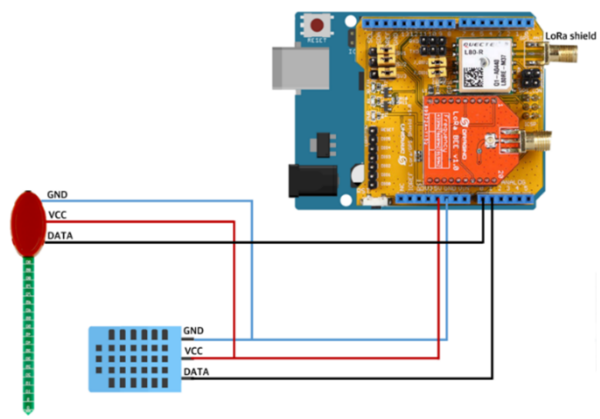

Fig. 1. Circuit of sensor node

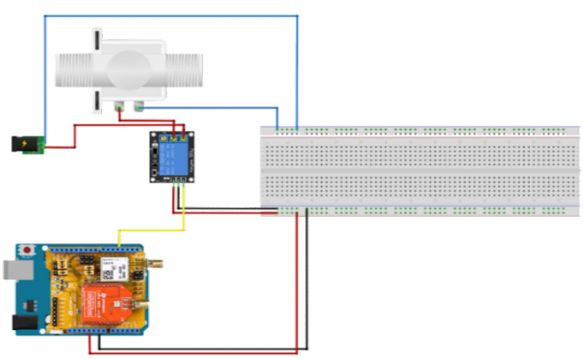

Fig. 2. Circuit of actuator node

The sensors required are DHT11, VH400, Solenoid Valve, and a relay module, as shown in Table 1. DHT11 sensor receives soil humidity and temperature and has the features as shown in [16, Table 2]. VH400 sensor receives soil moisture data and has features as shown in [17, Table 3]. In the sensor node, as shown in Fig. 1., the LoRa/GPS shield of Dragino is attached to the Arduino and is connected with DHT11 and VH400. Raspberry Pi with a LoRa/GPS Hat is used as a gateway. Edge computing node for the irrigation is also a Raspberry Pi. The actuator node is attached to Arduino to LoRa/GPS shield of Dragino and is operated by the relay module of the high-level trigger and the solenoid valve, as shown in Fig. 2.

B. System Design

The overall system design of L&M Farm includes six components, as shown in Fig. 3.

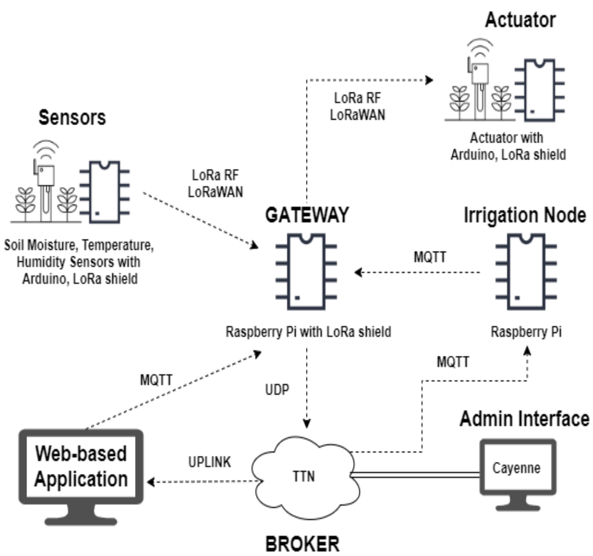

Fig. 3. Design of L&M Farm

The first component is the sensors. These sensors obtain soil moisture, temperature, and humidity data from soil and air. The sensors used in this project are shown in Table 1., and the circuit of the sensor node is shown in Fig. 1.

The second component is the gateway. This gateway is a Raspberry Pi with a LoRa/GPS Hat and registered in TTN (The Things Network) Cloud. It receives sensor data by Lora RF, LoRaWAN, and sends it to the TTN Cloud. Also, it receives data from the irrigation node and web-based application and decides whether to send a signal to the actuator using LoRa RF and LoRaWAN.

The third component is the TTN Cloud. TTN Cloud is a cloud that connects and manages exchange data from LoRa gateways [18]. TTN Cloud receives data from the packet forwarder installed in the gateway and uplinks to the web-based application. In addition, TTN Cloud is integrated with Cayenne, an interface for the administrator.

The fourth component is an irrigation node. This node is a Raspberry Pi which runs an Open Weather API. Open Weather API is an open-source weather API that allows getting 5 days weather forecast.

The fifth component is the actuator. This actuator is a solenoid valve that is connected to an Arduino. This valve is turned on automatically when the soil moisture is under 200. (soil moisture range). Moreover, it can be turned on/off by the farmer's decision using the web-based application.

The sixth component is a web-based application. The backend development was done by using Node JS, frontend using HTML/CSS, database using MySQL version 5.6. The web-based application's design was RWD (responsive web design), in order to meet farmers' needs to use the application on various devices, e.g. computers and smartphones.

C. MQTT Diagram

There are three MQTT diagrams that are used in the system design, as shown in Fig. 3. The diagrams for the actuator activating automatically due to the soil moisture are shown in Fig. 4. and 5. The diagram for the actuator activating manually from the web-based application is shown in Fig. 6.

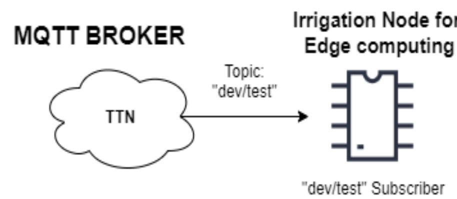

Fig. 4. MQTT diagram of controlling actuator automatically- sending data to irrigation node

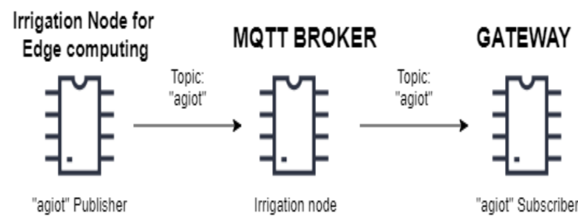

Fig. 5. MQTT diagram of controlling actuator automatically- sending data to actuator

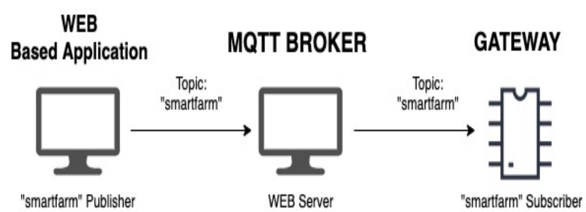

Fig. 6. MQTT diagram of controlling actuator by farmer's decision

First, when sending the sensor data to the irrigation node, as shown in Fig. 4. TTN Cloud acts as an MQTT Broker. Irrigation node for edge computing acts as a subscriber for the "dev/test" topic. After appending data from the Open Weather API, it sends it to the LoRa gateway as shown in Fig. 5. The irrigation node, the Raspberry pi with Mosquitto Broker installed, is the publisher of "agiot" and act as the MQTT Broker. The LoRa gateway is the subscriber of the topic "agiot", which receives the sensor data and weather data in a string.

In Fig. 6., a web-based application is an MQTT publisher of the topic "smartfarm". The gateway, the subscriber of "smartfarm" receives the farmer's decision and sends it to the actuator by LoRa. The broker for this diagram is Eclipse Mosquitto, an open-source message broker [19].

D. Flowchart

Fig. 7. shows the flowchart of the Arduino receiving humidity and temperature data from DHT11 and soil moisture data from VH400, displaying the data, and sending a packet by LoRa.

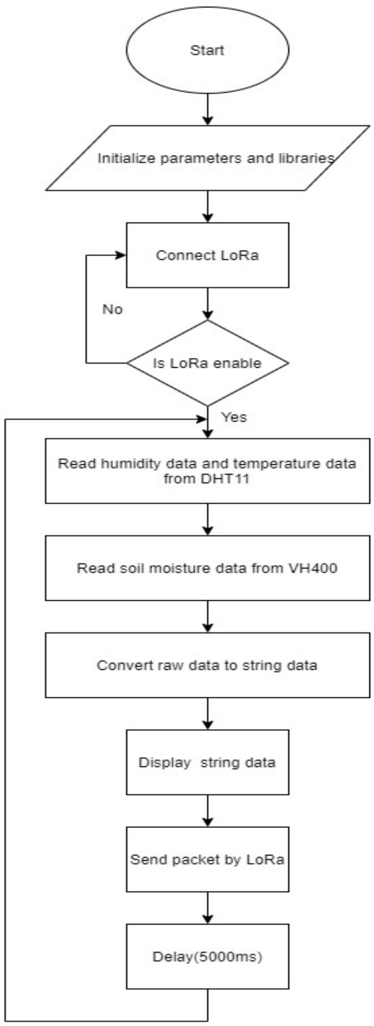

Fig. 7. Flowchart of the sensor node

Fig. 8. shows the flowchart of the gateway i.e., data transmitter received from sensor node to TTN Cloud, data transmitter received from irrigation node to actuator node, and data transmitter received from local server to actuator node.

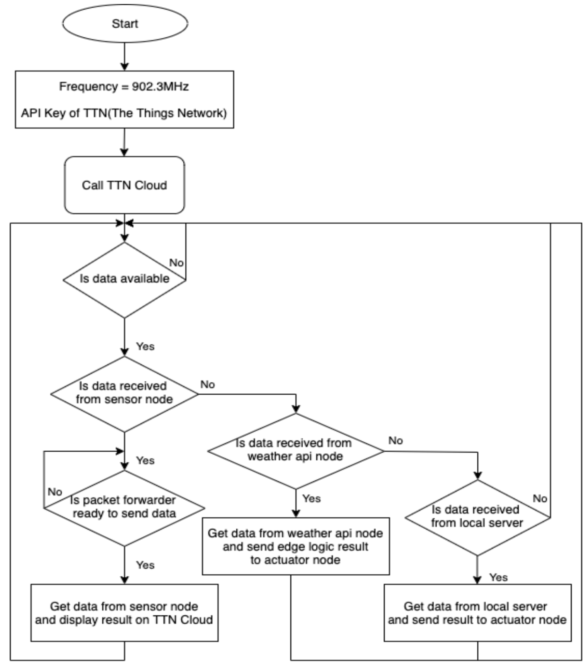

Fig. 8. Flowchart of gateway

Fig. 9. shows the flowchart of the irrigation node. When the irrigation node gets sensor data from MQTT Broker, the irrigation node gets weather data from Open Weather API and adds that data to the sensor data. Finally, the data is sent to the gateway.

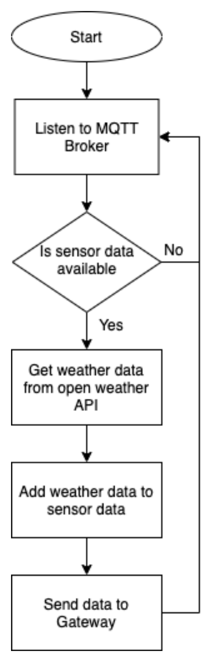

Fig. 9. Flowchart of irrigation node

Fig. 10. shows the flowchart of the actuator node, in which the initial settings must be finished, as shown in Fig. 2. The actuator node receives data from the gateway. It turns on the actuator when it receives '1' and turns it off when the data is '0'.

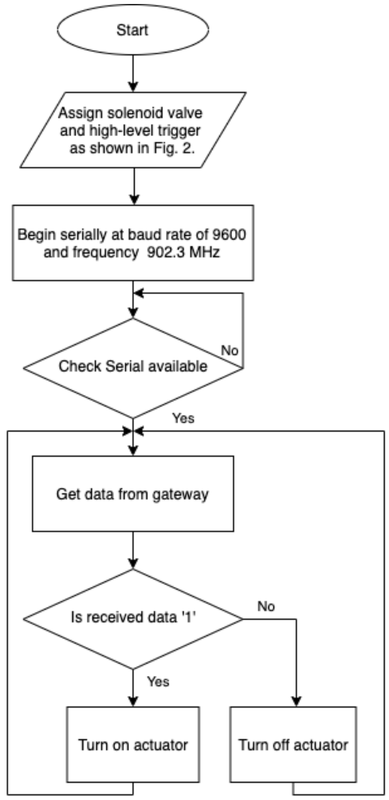

Fig. 10. Flowchart of the actuator node

E. Service Scenario

Fig.11. shows a scenario when the user operates the actuator manually using a web-based application. The user controls on or off via web-based application. On the web-based application, the user's control is published to the broker Mosquitto, and the gateway subscribes to that information. The gateway sends a signal to the actuator using LoRa to turn the actuator on or off. Gateway responds to the changed actuator status and updates in the database. Finally, the changed result is reflected in the web-based application and the result is shown to the user.

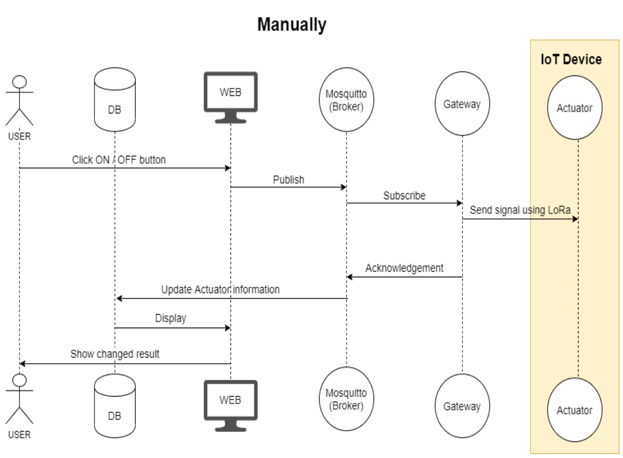

Fig. 11. Actuator operation scenario when the user manually controls

Fig. 12. shows a scenario when the actuator is operated automatically without user control. The sensor node sends the soil moisture value to the gateway. The gateway uplinks to the TTN and the TTN downlinks to the irrigation node, which is an edge node. Since this node has five-day weather forecast information, it sends the weather information and the soil moisture value to the gateway. The gateway uses these values and sends on or off signal to the actuator. The above process is repeated at regular intervals.

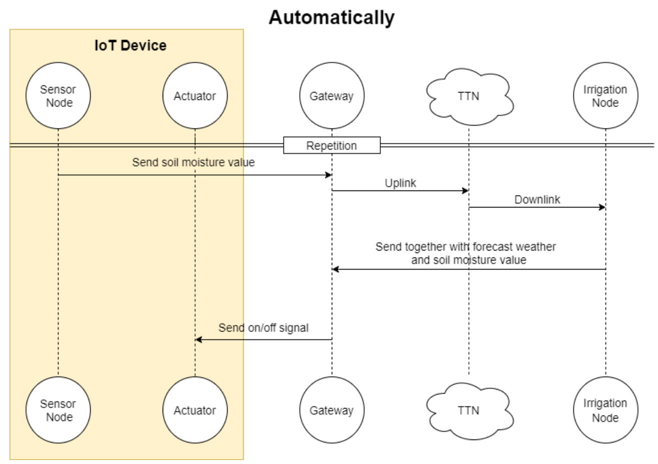

Fig. 12. Automatically actuator operation scenario

IV. Implementation Result

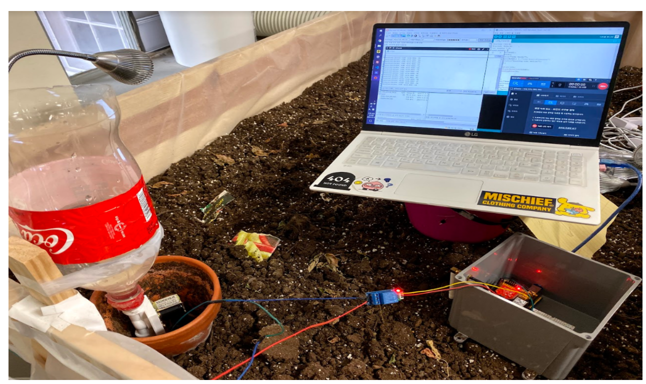

Fig. 13. L&M Farm prototype

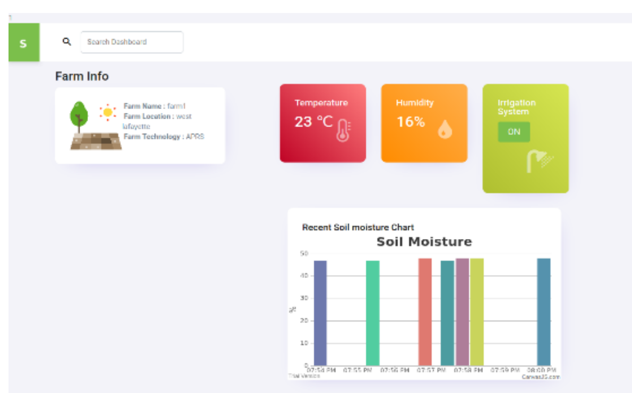

Fig. 14. My farm page

The prototype was designed before installation on the farm, as shown in Fig.13. The prototyping environment was conducted in a small garden 1.2 m * 2.0 m in the K-SW Square of Purdue University. The web server operated on a local server.

Fig. 14. is the web-based application's my farm page. This page shows temperature, humidity, soil moisture data which was collected from the sensors installed at the smart farm. There is an irrigation "ON/OFF" button, which shows whether the actuator is turned "ON/OFF". When the farmer clicks on the button, the actuator can be activated manually.

VI. CONCLUSION

This paper presented L&M Farm, a smart farm based on LoRa and MQTT. LoRa pays dividends on cost and power consumption efficiency while covering larger areas than other options. Thus, it would be practical, sensible to base LoRa as the decision on the network technology for smart farms. Also, the MQTT protocol complements the previous smart farm studies' lack of assurance on lightweight, security, and reliability of data transmission.

Although this paper proposes a design that intends to ameliorate previous suggestions on smart farms, it still has its weaknesses. The inclusion of TTN Cloud to manage the LoRa gateway, resulted in the prerequisite of internet connection. Since, the quality of internet connection at outdoors is not guaranteed, an idealistic irrigation system should be able to perform under any circumstances e.g. no internet connection.

Therefore, the goal of our future work is to build the entire ecosystem without the need of an internet connection. Also, to increase the feasibility of the edge logic, weather information earned from the Open Weather API will be considered. Moreover, the strengthen prototype will be implemented on an outdoor farm to verify the actual feasibility.

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