The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #41653

LoRaWAN Solution for Automated Water Drainage of Agricultural Fields

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Abstract: Eastern North Carolina farmlands are often below the standing water level, facing a unique challenge that requires constant drainage to avoid flooding. Irrigation canals collect water from multiple farms, and they must be emptied regularly to maintain crop viability and to protect property like equipment and structures. Maintaining a low water level in these canals is a critical component of the daily tasks farmers must manage. In most cases, this process requires a visit to the location of the pumps and turning them on for a given amount of time, a labor-intensive and time-consuming activity. In this paper we discuss the development of an automated solution using ultrasound sensors to measure surface water levels networked over LoRaWAN with smart actuators that can remotely turn the pump on and off. Machine Learning based automation algorithms provide an optimization of workflow, with the necessary redundancy built in. The solution offers the flexibility to tailor itself to suit the performance characteristics of the pumps used in these farmlands, maximizing efficiency and resource utilization, no matter the environment. Farmers are provided with water level visualization tools accessible on mobile devices that provide a comprehensible overview of the water levels over a period of time. As well, intelligent notifications alert farmers to any anomalies or failures, enabling quick intervention to minimize downtime and prevent crop damage. Future expansion options for this solution are discussed, such as integration of weather forecasts and live weather data and sensors' deployment in fuel reservoirs to ensure the pump can run optimally.

Key words: IoT, LoRa, Sensors, Smart Agriculture, Water Management

1. Introduction

The rising prevalence of Internet of Things (IoT) devices is reshaping industries [1]. One key advantage is enhanced efficiency and automation, as IoT devices can collect and analyze real-time data, facilitating informed decision-making and process optimization. Using sensing IoT devices enables proactive and preventive detection of issues. This approach ensures the reliability of the system, optimizing overall performance.

LoRa (Long Range) [2] is a low power, long range wireless communication protocol used for IoT devices. This is achieved through its Chirp Spread Spectrum (CSS) approach to signaling [3]. It is well suited for sending small packets, such as sensor data, over wide areas. This is optimal for use cases such as smart cities, environmental monitoring, and most importantly, smart agriculture.

This paper will go over the work of using LoRa enabled sensors to develop a solution for farms that have to manage excess water. This solution is part of a project from the Center for IoT Engineering and Innovation [4] to aid farmers in Eastern North Carolina.

2. Problem Definition and Requirements

Situated in Eastern North Carolina, Middle Creek Farms faces a persistent challenge of excessive water, posing a risk of flooding and potential harm to both equipment and crops. Recognizing the need for an efficient solution, the Center for IoT Engineering and Innovation has strategically deployed ultrasound sensors within the irrigation canals managed by the farm. These sensors serve a crucial role in continuously monitoring water levels and promptly notifying the farmer when they approach critical levels. This real-time monitoring and alert system provides an early warning, enabling the farmer to take preventive measures and mitigate the risk of flooding. However, the current remediation process involves the manual toggling of the water pump, demanding the farmer's time and energy. On average, it takes around four to five hours of constant pumping for the reservoir to return to an acceptable level.

An automated solution to this problem must observe the following requirements:

- **Seamless Communication Between Sensors and Actuator –** Ultrasound distance measuring sensors present in the environment should be able to trigger a smart actuator toggling power for the pump according to a predefined algorithm.
- **Optimal Draining Based on Environment –** A machine learning algorithm that optimizes fuel and time efficiency will be used to detect when to optimally toggle pump status.

- **Visualized Data and Notifications** – The solution should allow for water levels to be visualized and should be able to send notifications to the user if needed.

In this paper we describe the process of designing and testing the proposed solution that meets these requirements.

3. Literature Review

The problem we are addressing in this paper falls in the category of smart agriculture [5,6] and more specifically, the management of excess or shortage of water. The use of IoT in combination with expert systems or Artificial Intelligence is widely perceived as the answer to managing and automating many agricultural workflows including water management. An example of an architecture for a broader scope agricultural monitoring system using LoRaWAN is presented by P. Indira et al. [7]. In general, various solutions have been developed involving various sensing technologies, various communications technologies, and various backend technologies for managing data, data processing and data visualization [8,9].

LoRaWAN is a relatively new technology, however, it is rapidly being adopted as an effective communications protocol for sensing solutions, including smart agriculture solutions [10]. We selected LoRaWAN for our solution as well since it is a cost effective, easy to manage option for farms in the geographical context of Eastern North Carolina where a flat terrain facilitates long ranges coverage for LoRa gateways. Previous work by Usmonov and Gregoretti [11] and by Basu et al. [12] are examples of similar solutions developed around LoRa to address water management in the context of smart agriculture. Our work developed the solution for the described use case on top of a sensing platform built by ECU and used by multiple interdisciplinary projects attempting to monitor various variables in real-time and to automate workflows. On this platform [13] centered around LoRa however, capable of supporting other communication protocols as well, we are leveraging a high-performance, non-relational database optimized for time series data structure and on cloud resources utilized for service delivery, data collection and workflow automation. The detailed description of the platform is outside the scope of the paper but it can be reviewed at the provided reference [13].

4. Our Implementation and Results

The solution to the problem stated at the beginning of the paper is to implement a system that monitors the water level in irrigation canals in real-time, generates operational decisions driven by the weather conditions and current water levels, and turns on the pumps at the appropriate time and for the appropriate duration to maximize the benefits for the farmer. The ultrasonic sensors that detect water levels were deployed in the irrigation canal close to the water pump as shown in Figure 1.

Figure 1, LoRaWAN enabled ultrasound sensor deployed for water level monitoring.

The sensor used in this solution is a Dragino LDDS75 LoRaWAN Distance Detection Sensor [14]. The ultrasound sensor was selected for its accuracy which was tested extensively in multiple water level monitoring deployments in Eastern North Carolina [15]. It was also selected for its low cost ($70) and ease of installation and management. The sensor can run on a Lithium-ion battery for over a year if measurements are taken every two hours.

The sensors transmit their data and receive instructions through the LoRaWAN communication protocol [2] enabled by a Cisco LoRa gateway (Figure 2) which is integrated in and managed by the PITON (Platform for IoT Open Networks) platform [16] developed and maintained by ECU's Center for IoT Engineering and Innovation (CIEI). PITON provides the infrastructure and services necessary to easily deploy and manage LoRa enabled sensors.

Figure 2, LoRaWAN gateway deployed on the premises of the farm.

The gateway was installed on a grain elevator, and it provides coverage up to 5 miles which is sufficient for the needs of the solution and the development of other smart agriculture solutions. The gateway is connected via a point-to-point WiFi link to a Starlink router which provides local internet access. The gateway, the sensors and actuators are managed by the PITON platform.

The collected data is stored in an InfluxDB database and the real-time sensor data is visualized using a custom-made dashboard on Grafana (Figure 3).

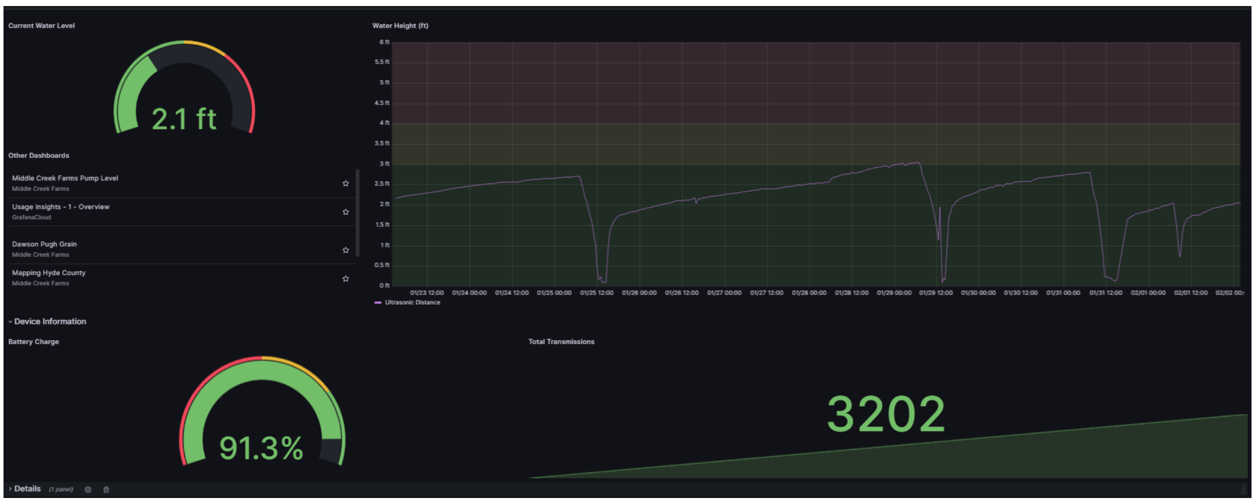

Figure 3, Real-time water level data from the irrigation canal.

The graph shows the most recent data for the previous 10 days. The accumulation of water and the effect of pumping are clearly seen in the data pattern. It takes several hours for the pump to fully evacuate the water at the point of measurement. Two thresholds configured for alerting purposes. When the water level goes above the acceptable level, an email and an SMS notification are automatically sent to a designated point of contact. Additionally, two consecutive data transmissions ae missing, another notification is generated to address the possibility that a sensor has been compromised. Both of these two alert algorithms provide resilience for the solution as they represent a backup mechanism for the case where the pump failed to start or to operate and for the case when the sensors are compromised.

For the proposed solution, we need to add actuation and automation to trigger the start and stop of the pump based on the readings of the water level sensor. We plan on using an enginko Wireless

Actuator [17]. This device can receive the necessary commands over LoRaWAN network, from PITON based on predefined and automated heuristics. Sensors will also be installed in the fuel tanks to monitor the diesel fuel levels as well as to help model the optimal operational cycle for the pump. The pump present on the farm is a legacy model, so preserving fuel is also a priority of the end solution. The actuator should take in data from both sets of ultrasound sensors and switch on and off according to the automation algorithm.

The architecture of this solution is captured below (Figure 4). The ultrasound sensors present in the irrigation channel will send the data of the current water level to the LoRaWAN gateway deployed on-site. The data is transmitted to the PITON platform, where it is decided if the water level has reached a critical level. If so, a signal is sent to the actuator to begin the pumping process. Future iterations of this solution will include redundancy of ultrasound sensors and LoRa actuators. Additionally, with the implementation of the machine learning algorithm, data sourced from meteorological sensors will be incorporated for analysis, allowing for preemptive management of the reservoirs.

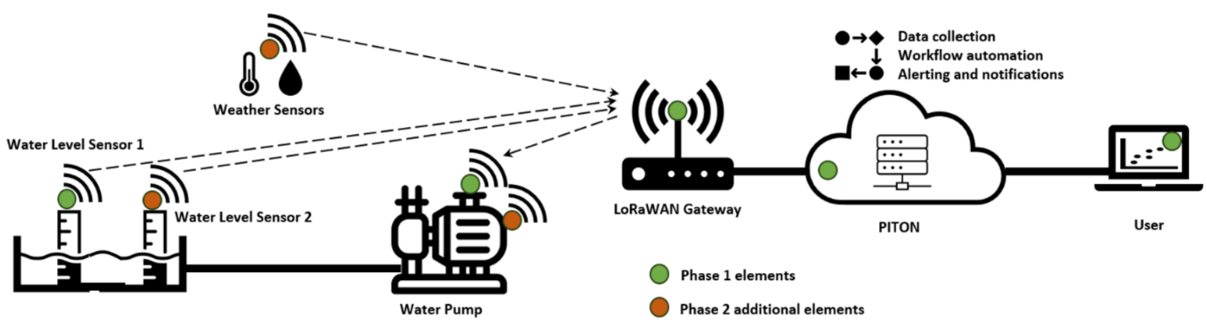

Figure 4, Solution architecture.

It is important to take the time to briefly address the security considerations of the architecture shown in Figure 4. The solution relies on the built-in features of LoRaWAN [18], a protocol developed with security in mind from day one. The LoRaWAN specific security features are combined with hardened and secured gateways, encrypted communication between the gateways and the network server and the applications server, resources managed by the PITON platform. The LoRaWAN deployment follows the industry best practices. Only certified, hardened devices are used, and the keys used in the symmetric cryptography used by LoRaWAN are secured. The PITON backend operates in a SaaS model which runs on an Azure virtual private cloud.

Considering the specific use case addressed by the solution, multiple layers of resiliency should be considered to ensure maximum uptime and avoid the negative impact of flooding in case of failure. A more extensive set of notifications must be implemented to provide additional checks on the operation of the solution. Physical redundancy should be implemented in follow up phases as shown in Figure 4. Additional sensors will alert users in case of any reported discrepancies in the water level. An additional actuator can act as a failover in case of the main actuator failing, minimizing downtime and potential damages. A manual option to toggle the pump's status must be implemented as well in case of a critical network failure.

Limitations of this solution include the reliance on reliable network connectivity, which may be challenging for farms in rural areas with limited infrastructure. This limitation of the current architecture will be addressed by implementing a full LoRaWAN stack locally thus supporting the end-to-end functionality without the need for internet access. The challenge with this approach relates to manageability, software, and algorithm updates. For these reasons, a hybrid approach is appealing with respect to addressing manageability an autonomous operation.

5. Conclusions and Future Work

This project is the first step towards a complete workflow automation for managing excess water in Eastern North Carolina Farms. The solution is using tested LoRaWAN enabled surface water level sensors and actuators managed and controlled by the ECU developed PITON platform. The solution has already proven its value to the owner of the farm where we did our proof of concept. Access to real-time data and alerting provides piece of mind while workflow automation eliminates the need for regular trips to turn the pump on and off. The feedback has been very positive. We also believe the solution creates the opportunity for additional future investigations and development in the area of intelligent decision making. We intend to use ML to develop an optimal operating model for the specific pump type used on this farm. Additionally, the PITON platform provides the option to import other real-time or batch data sources including local weather information and forecast. We intend to use ML to further optimize the use of the pump and subsequently the consumption of diesel fuel by predicting utilization based on weather information. Preemptive activation of the pump ahead of storms will ensure more effective irrigation and minimize the effects of the storm.

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