# SANTA CLARA UNIVERSITY
## DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED

# Hydration Automation: Smart Tank

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# Hydration Automation: Smart Tank

by

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# Hydration Automation: Smart Tank

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ABSTRACT

Agriculture is a huge field that can benefit from Internet of Things (IoT) with many solutions focused around the monitoring and management of water in irrigation or storage systems. Different types of sensors to measure water quality, amount, flow and pressure are used to monitor the health of these systems and actuators are deployed like pumps or valves to manage the water in theses systems. The Hydration Automation (HA) automated water monitoring and management system utilizes low cost, small form factor, and sustainable Sensing Units (SUs) to collect water level reading of water storage systems through the use of an ultrasonic sensor and Actuating Units (AUs) for automating the control of valves and pumps that are operated via a Base Station. The SUs and AUs are housed in water proof, cost effective, and environmentally friendly 3D-printed casings and often placed miles away from each other in agricultural lands. This necessitates the existence of a long range communication subsystem which utilizes the ÂB communication protocol atop of LoRa or other link layer protocols.

This setup of the HA system, however effective, for monitoring and operating multi-tank irrigation systems, is an overkill for systems comprising of only a single water tank. Furthermore, the HA system thus far, had not included a mechanism for emptying the water tanks or for decreasing the existing water levels in the tank when needed for preventing damage to the tanks when freezing of the water was possible. This thesis discusses the implementation of a smart tank for the HA system which is comprised of an AU for water level control automation and is controlled directly by a slightly improved SU rather than a specialized Base Station.

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# Chapter 1

# Introduction

## 1.1 Motivation

Agriculture is dependent on water with farms, greenhouses, orchards, ranches, and vineyards all in need of irrigation systems. Modern irrigation systems are equipped with an assortment of water reserves, sheds, and tanks to store water for later use or to manage the flow, time, or quality of the water delivered to the crops.

Irrigation systems are a strong candidate for agricultural automation via an Internet of Things (Iot) approach [1, 2, 3] as they include many mechanical components such as pumps and valves that lend themselves well to automation and control. Pumps can be turned on when more water is needed in the system and turned off when the system is full or off duty. Valves can be opened or closed based on sensed need in the system or an optimal irrigation schedule [4] that changes when seasons change or when crops are rotated. For example, a rancher who rotates his livestock between different pastures (graze lands) will have need for an irrigation system which diverts water to the currently in use pasture only. Hence certain water tank(s) will need to be filled and kept filled via a certain chain of valves that open and close at the appropriate times as well as certain pump(s) which turn on and off at the correct times when the valves are opened or closed. Many industrial grade irrigation system solutions exist which utilize complex, over sized, energy inefficient, and cost prohibitive components. Such solutions are thus only accessible for purchase, installation, and maintenance to big agribusiness or well-off customers. This leaves out smaller local farms and ranches as well as nearly the entire agriculture of the developing countries where farmers and ranchers are forced to utilize more labor intensive yet less energy efficient and/or less environmentally friendly methods of transporting water from the source to their crops [5]. So agriculture IoT solutions require systems that are robust, reliable, sustainable, and have a small form factor as well as being low cost.

Hydration Automation (HA) [6] is an automated water monitoring and management system that meets these requirements. HA consists of many Sensing Units (SUs) [7], Relay Units (RUs), Actuating Units (AUs), and a Base Station. The units are built using off the shelf components that are encased in water proof, cost effective, and sustainable 3D printing containers [8]. The SUs wirelessly communicate with other system units, RUs and Base Station, through a robust communication subsystem utilizing a custom in-house developed routing protocol called ÂB [9]. To control the management of water, the AUs are controlled by the Base Station which is informed by the SUs monitoring each of the water storage tanks. This thesis reports on the extension of the SU implementation and combines it with the AU to create a smart water tank that is able to be used and integrated into the HA system or used separately.

## 1.2 Related Work

Using IoT systems for monitoring and managing water usage is not a new subject and many implementations have been made. These solutions revolve around water management and monitoring for smart cities, villages or homes. Researchers in [10] propose a solution to monitor the quality and distribution of water in villages as well as cities using LoRa and LoRaWAN. Another [11], deploys ultrasonic sensors to monitor water tank levels around a large campus. Others use different types of sensing with their system like in [12], where they present a smart water network with LoRa for cities to collect data on water pressure and flow to detect pipe leakages and then stop them through closing valves to prevent more water loss. As reported in [13] and [14], researchers have looked at solutions to minimize or reduce water consummation or waste for homes. The first implements a smart tank to refill and distribute water in a home setting, while the second implements a system for saving water in toilets. These solutions all revolve around water usage for humans but an import area for these types of solutions is in agriculture. Many of these solutions can be adapted to be used in an agricultural setting. In [15] and [16] researchers focus on agriculture. The first paper looks into smart irrigation systems, the technologies that can be used, and what types of sensors would be needed or could be used for this type of task. The other paper proposes a system for a smart farm automated irrigation system that contains a water tank monitoring and control subsystem which is simulated using MATLAB to verify feasibility. Even though the authors of that paper did not report building the system physically, their simulation provides great support for the feasibility of the idea.

We define a smart tank as a system that monitors a water storage container through different sensors and manages the amount of water through the use of valves or pumps. Smart tanks are used for a variety of applications. One include the use in a green house [17] where an underground tank is monitored which is then used for a drip irrigation system. Another use is in an aquarium setting [18]. They use a smart tank to regulate the temperature, water, pH and Dissolved Oxygen (DO) levels through the use of valves, pumps and sensors. Others use it for smart houses as discussed before in another implementation [19], where the level and turbidity of the water is measured and a pump can be remotely controlled to refill the water tanks in the home. A similar application [20] also performs water tank level monitoring and management through ultrasonic sensors and pumps in a home setting. Finally, smart tanks are used in farming in Uganda [21], where they use solar pumps to pump water from wells to refill tanks that are used for an irrigation system where the soil moisture levels are tracked.

# Chapter 2

# Overall System

The smart tank is part of the overall HA system, which can be seen in Figure 2.1. The system consists of four main components: the Base Station, Relay Unit (RU), Sensor Unit (SU), and Actuating Unit (AU). The SU collects data from the water tanks that they are connected to, then sends the data over LoRa (or other data link layer protocols as proposed in [22]) to either the Base Station directly or through an RU (or network of RUs) if the range needs to be extended due to line of sight issues or distance. The SUs are designed to be low cost, small factor, and sustainable. The Base Station collects all the data from the SUs and uploads them either through WiFi or GSM to a web application to store the data. The automation of the system comes from the AUs in the system. The AUs can either be controlled by the Base Station or an SU depending on the environment in where it is deployed. The system uses LoRa to communicate between the SUs, RUs, and Base Station using an energy aware communications protocol called ÂB [9]. More detailed descriptions of the system as well as the evolution of the system over time can be found in [7], [8], and [6].

## 2.1 System Components

### 2.1.1 ÂB Energy Aware Communication Protocol

The HA system uses ÂB, which is a green protocol known as Energy Aware Communication Protocol (EACP) that takes advantage of the low power sleep modes on IoT devices by synchronizing the sleep cycles of all devices on the network. This protocol is able to help reduce memory consumption and allows for a more power efficient operation. The protocol aims to serve as a foundation for projects in IoT applications to work within the constraints of the hardware, while providing some of the same functionality as a system with more resources at its disposal. The system uses ÂB to communicate with other nodes in the network, such as Relay Units (RUs) and the base station. ÂB is a protocol designed from the ground up for IoT devices which takes advantage of the devices' sleep cycles in order to reduce the overall energy usage of the system as a whole. ÂB's original design is to provide network layer support (a.k.a. routing) to IoT systems that utilize Semtech's LoRa [23] as their Link layer OSI model's combined Data Link

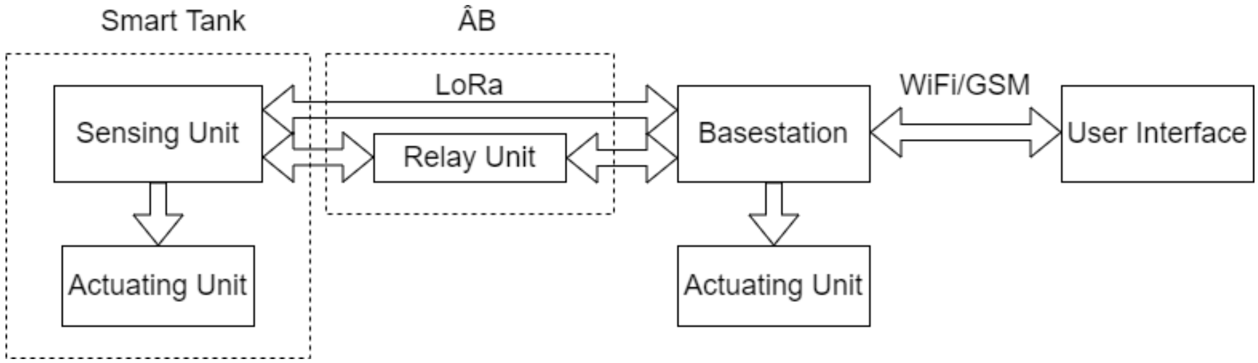



Figure 2.1: HA System Architecture

and Physical layers communication protocol. However, ÂB is built in a modular and medium access independent manner as to allow for its utilization with any existing Link layer protocol.

### 2.1.2 SU

The SU is the device that collects data in the HA system. This data is gathered from a variety of different sensors that can monitor the weather or climate, tanks or ponds, soil moisture, or other agricultural needs. This dissertation focuses on data collection of weather or climate information and water tank levels. The SUs use the ÂB protocol and LoRa communication to send the gathered data to the Base Station or an RU. An SU can use its collected data and controls an AU to manage the water level in a water tank. The SUs were designed to be low cost, small factor, and sustainable with easy-to-replace parts if part of the hardware is damaged. An SU with its case open can be seen in Figure 2.2.

### 2.1.3 AU

The AU is part of the HA system that controls the automation of irrigation, pumps or valves on a farm. This dissertation focuses on the control of pumps or valves for water tank management. An AU is connected to either an SU or the Base Station which determines when to open or close valves and turn on or off pumps. This is determined based on the collected data from an SU.

### 2.1.4 RU

The RU is a range extender for the HA system that passes along the information from SUs or other RUs. If the locations of the SUs are relatively far from the Base Station or spread in a non-signal friendly environment such as mountainous, densely packed forest, or building structures then the subsystem will utilize RUs which serve as signal bouncing stations. They allow the SUs to be outside of the direct range or line of sight of the Base Station and therefore enable communications to continue so long as any path from a given SU to the Base Station exists.

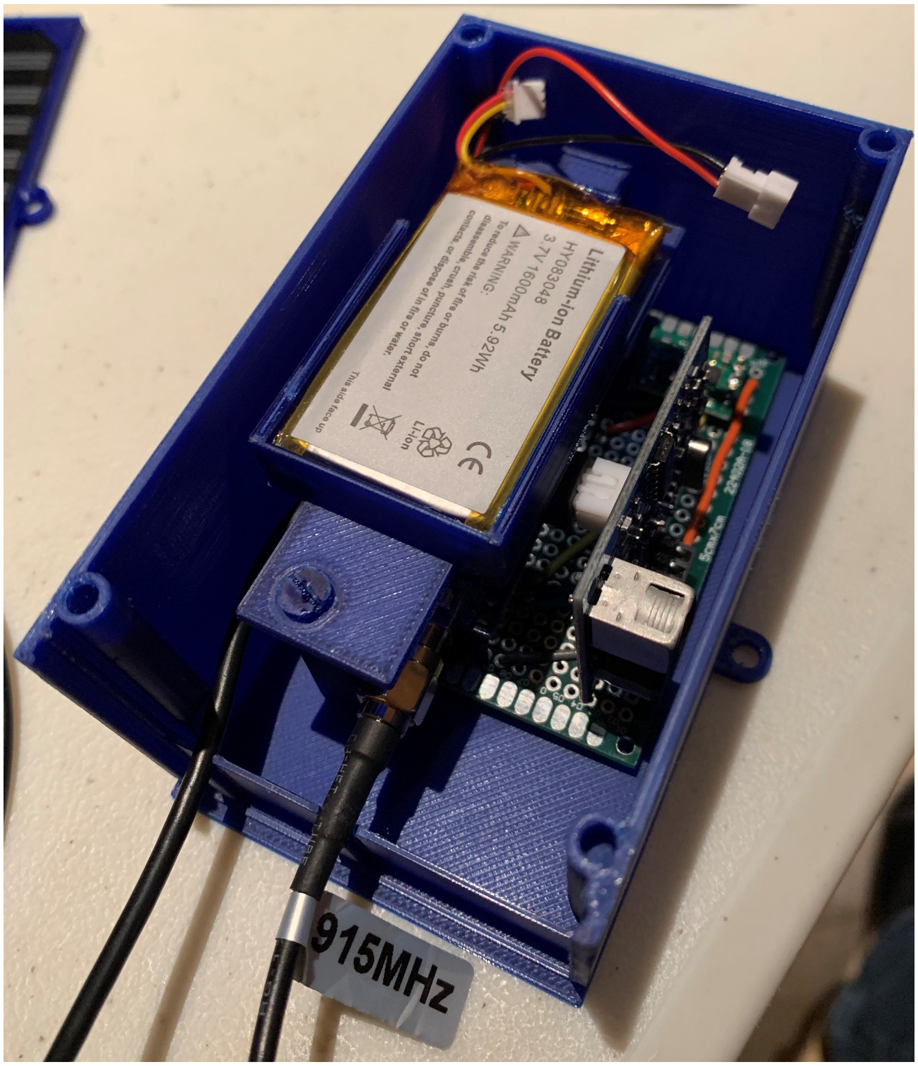


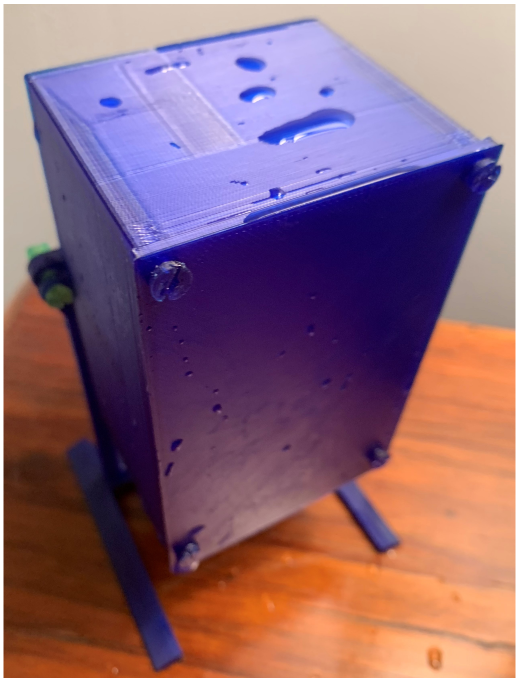

Figure 2.2: Sensing Unit (SU) Device with Case Open

### 2.1.5 Base Station

The Base Station is the end node in the system to where all the SUs or RUs send the collected data. This collected data is uploaded to the cloud for storage via WiFi or GSM depending on the communication that is available in the installed environment. From there the data can be visualized and analyzed to show water usage over a period of time.

### 2.1.6 Custom 3D Printed Casing

The HA system has custom 3D printed Casings for the SUs and RUs in the system as they are exposed to the elements and intended for long-term use outdoors. The cases were designed to withstand storms, intense daily sunlight, or other environmental abuse present on a farm or ranch. With this in mind, Polyethylene Terephthalate Glycol (PETG) filament was used in all parts because it has been proven to be resistant to harsh environmental elements such as rain,



(a) Wet capsule mounted on vertical frame

(b) Interior overview after water testing

Figure 2.3: SU and RU Waterproofing Testings Results

prolonged exposure to sunlight, and even acidic conditions. The results from waterproofing tests can be seen in Figure 2.3. The SUs and RUs use the same casing design to make it easier to print and because they use the same base hardware.

# Chapter 3

# HA Smart Tank

## 3.1 System Architecture

The smart tank designed and implemented for the HA system consists of an AU controlled by an SU. An AU uses a valve or a pump to control the flow of water into the water storage device or tank. This is controlled by a whisper node which uses a relay that acts as a switch. The whisper node has an ultrasonic sensor to detect the distance to the water in the tank which is used to calculate how full the tank is, how much water is needed to refill the tank and how long it will take to refill the tank. A temperature sensor is used to measure the temperature of the environment the device is installed in and an SD card module is attached to keep a local record of the collected distances and temperatures. This system is powered by a solar panel that charges a battery. An overview of the smart tank architecture can be seen in Figure 3.1 in which an SU controls an AU.

## 3.2 Configurations

The AU in the smart tank system can be setup with two different configurations. In the first configuration the AU is controlled by an SU. In the second, the Base Station controls the AU. These two configurations are used based on the environment in which the system is installed. There are two configurations due to the power required to operate a valve or pump as well as whether a more real time reading of the water level is wanted when the valve or pump is active. To have the Base Station or SU control the AU, a power source that is able to meet the requirements of the valve or pumps is necessary. If more than 5V is required to operate the AU, a power source of an outdoor electrical outlet or a more powerful solar panel can be used since the system is meant for rural farms. The Base Station in the HA system is installed in a location that is near a pump or valve station which can contain multiple valves or pumps that lead to the individual tanks. Since the Base Station will be in an active listening or idle mode and not in a sleep mode it requires a powerful solar panel to be installed. This solar panel can be used to power the pumps or valves. While for each SU, a more powerful solar panel needs to be installed at each location. Depending on the situation, a hybrid of these two approaches could be used as well if valves or pumps are spread across a large area. The main benefit of having an AU

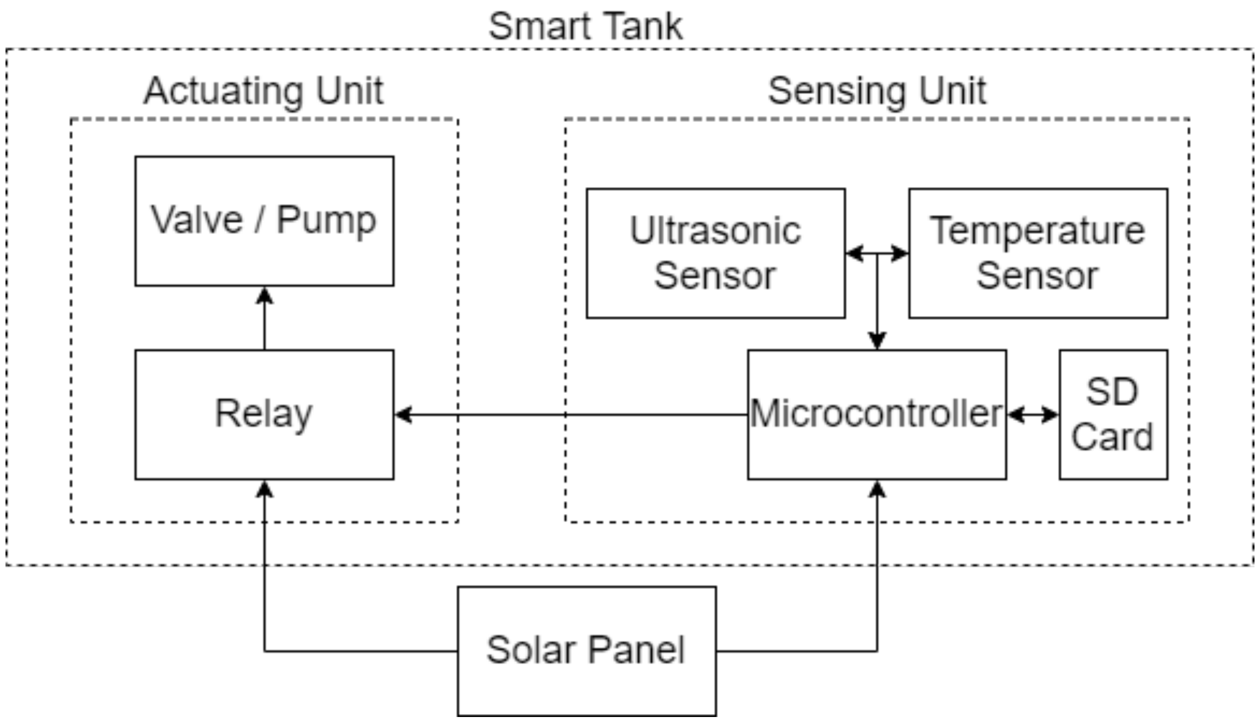


Figure 3.1: Smart Tank System Architecture

controlled by an SU is that real time readings of the tank while it is refilling is gathered to ensure that the water level does not overflow the tank. The other benefit is when the pumps or valves are spread out or near the tanks and not all in the same area, as only one Base Station is installed per farm while multiple SUs are installed. The Base Station setup could achieve almost real time readings but will then require the communication between the SU and Base Station to be almost constant which will require more power as well as could be delayed if there are other SUs or RUs trying to communicate with the Base Station.

A different use of the AU is for releasing water from the water tank. This allows for a mechanism to remove water from the tank that is installed in an environment where there is the possibility of the water freezing. If water in the tank is frozen and there is enough inside the tank, the expansion of the water due to freezing could damage and potentially cause the tank to burst or leak. This causes a lost of water that can be prevented through the use of an AU. The system uses the temperature sensor to determine whether the temperature near the tank is near freezing and will release some water to keep the water flowing and decrease the volume so that the tank is not completely full.

## 3.3 Hardware

The components of the previously designed SU include a Wisen Whisper Node [24] board with an on-board LoRa (Long Range) communication module [23], a JSN-SR04t Ultrasonic Sensor [25], a temperature sensor [26], a voltage regulator, a TP4056 battery charge controller [27], a 5W lithium battery pack, and a 5V 100 mAh solar panel. An

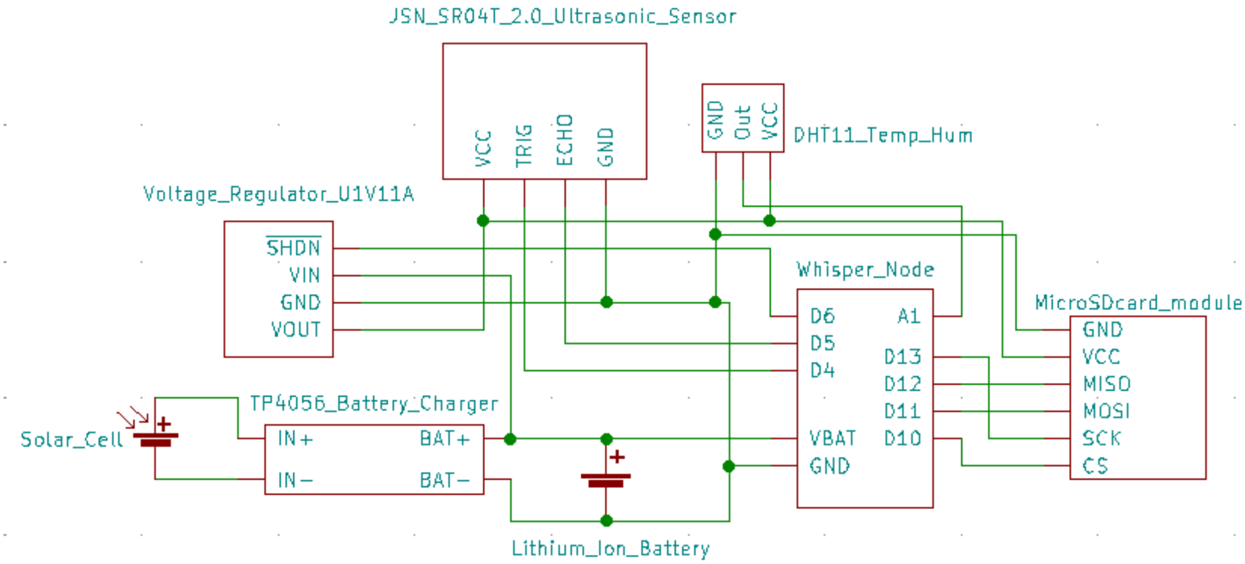



Figure 3.2: Sensing Unit Schematic

improvement to the SU is a MicroSD card adapter module [28] to enable local storage of data and resilience in the case of network failure or device failure. This also allows for storage of things like a device or tank ID or other information about the system. A schematic of the improved SU can be seen in Figure 3.2.

For prototyping purposes the components of the AU include a Solid State Relay [29] and an Orbit sprinkler valve [30]. The valve on the Orbit is controlled by a solenoid which opens a plunger that allows the flow of water. This model is able to handle 120 psi which is more than enough for testing purposes. The Orbit valve has two 3/4 inch female hose threads which enables it to be connected inline with a pipe. This thread size might not work with all water pipe systems so a valve that fits with the requirements of that system should be chosen for the appropriate pipe adaptor. The Orbit valve operates at 24 VAC and the inrush current is around 0.35 A and the holding current is around 0.23 A. This power requirement can not be provided by the Whisper Node so an external power cable was used for testing while a solar panel will be used when the full system is installed. For the Whisper Node to be able to control the valve, a solid state relay was used that was able to handle the voltage specifications of the valve. The relay functions as a switch for the valve that the Whisper Node controls. The relay has four connections, connections 1 and 2 are for VAC, while connections 3 and 4 are for VDC. It is able to handle 24 to 380 VAC and an input of 3 to 32 VDC. The Whisper Node uses a digital pin connected to connection 3 on the relay with connection 4 connected to ground. 24 VAC is connected to the input of the valve and the common wire of the valve is connected to connection 2 of the relay. Connection 1 is connected to the GND of the 24 VAC power source. The relay has a snubber circuit build in to withstand high surge voltages to prevent damage when controlling the valve. A simplified schematic of this can be seen in Figure 3.3. These specific parts for the AU are not required for the system to run as they were used for

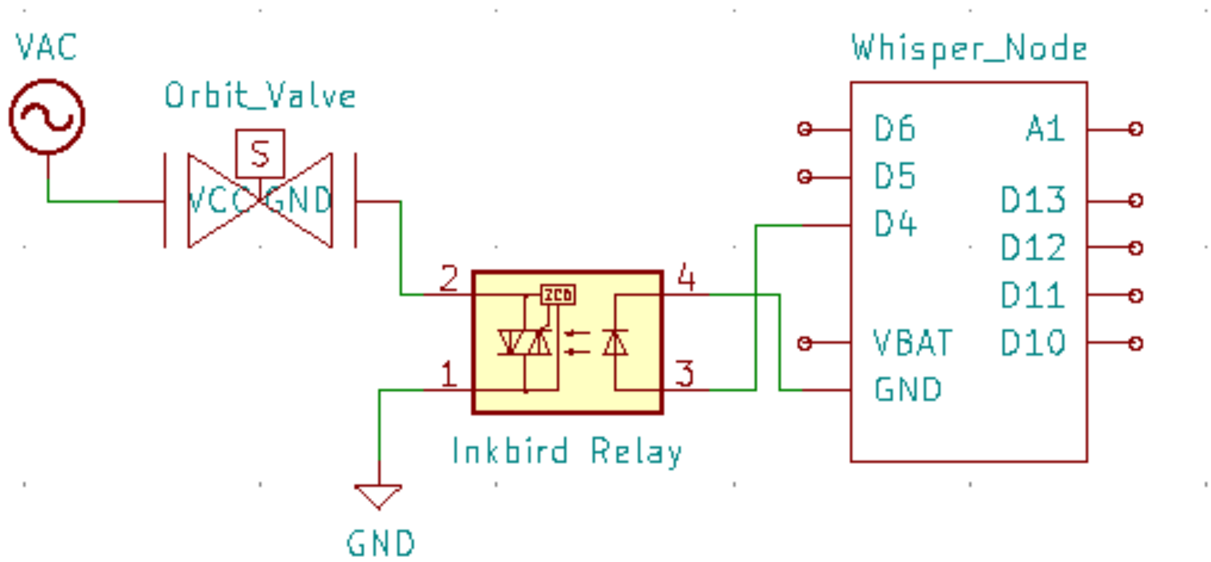



Figure 3.3: AU with Whisper Node Schematic

prototyping. However, they can be swapped to better fit the environment that the system is installed in.

## 3.4 Software

The process of water tank automation follows these steps when the SU controls the AU:

1. SU collects a distance reading of the water tank using the ultrasonic sensor.
2. Whisper Node calculates the current level in gallons of the water tank based on the predefined radius of the given tank.
3. The current level of the water as well as the ambient temperature is sent to the Base Station via LoRa.
4. Check if current volume is below a predefined threshold volume of the tank.
5. Calculate how long to open the valve to refill the tank to a desired volume using given flow rate and current volume.
6. Open the valve, then close the valve after calculated time has passed.
7. During this time, take distance readings to ensure that the tank does not overflow.
8. Collect the distance reading of the water tank again, and also the ambient temperature, and send them to the Base Station.

Instead of just using time to determine when to close the valve, the readings from the ultrasonic sensor can be used to determine when the tank has been filled to the desired level. Using this method causes more power to be consumed due to constant distance readings.

In a different setup where the Base Station controls AUs for each tank, the process follows similar steps:

1. SU collects a distance reading of the water tank using the ultrasonic sensor.
2. The distance reading and the ambient temperature are sent to the Base Station via LoRa.
3. The Base Station determines which valve needs to be controlled by the id of the message.
4. The Base Station Whisper Node calculates the current level in gallons of the water tank based on the predefined radius of the given tank.
5. Check if current volume is below a predefined threshold volume of the tank.
6. Calculate how long to open the valve to refill the tank to a desired volume using given flow rate and current volume.
7. Base Station sends the SU how long to sleep until the tank is refilled based on calculated time.
8. Open the valve, then close the valve after calculated time has passed.
9. SU wakes up and collects the distance reading of the water tank and the ambient temperature again and sends them to the Base Station.

During both of the configurations above the initial and final distances and temperatures are recorded to the Micro SD card that is connected to the system as a backup record of the readings.

In a final configuration of the SU controlling an AU to prevent tank damage in freezing temperatures the process follows:

1. SU collects a distance reading of the water tank using the ultrasonic sensor.
2. The distance reading and the ambient temperature are sent to the Base Station via LoRa.
3. Determine whether to open the valve based on the ambient temperature reading and the distance reading of the SU
4. Open the valve for a predetermined time to prevent freezing.
5. Collect the distance reading of the water tank and the ambient temperature again and send them to the Base Station.

# Chapter 4

# Smart Tank Testing

To test the smart tank system an SU was installed on a 5 gallon water bucket as a test water tank. The AU was controlled by the SU, and a garden hose was attached to the valve to provide water to the bucket. The valve was powered with a 24VAC wall adaptor. An SU was setup that controlled the valve and was tested to see if it could refill the bucket based on the distance reading that was collected. To gather the distance, the ultrasonic sensor was installed on the roof of the bucket lid. In this setup the Smart Tank was able to properly refill the tank bucket a set amount of water.

# Chapter 5

# Full System Testing and Installation

To test the robustness, usability and reliability of the HA system, the system is planned to be installed at Red Thistle Ranch. The ranch contains 125 acres of land with 7 water tank spread across the property. This ranch raises Scottish long hair cow and currently has around 12 cattle. An SU will be installed on each of the water tanks for a total of 7 SUs and 7 AUs, and the one Base Station will be installed at the pumping station on the property. The landscape has multiple hills which separate the pumping station and the water tanks. This causes problems in communication as LoRa requires line of sight to function. This is solved through the use of two RUs installed on the property in key locations allowing for all SUs to be able to communicate with the Base Station. An example of the spread of the water tanks on the property can be seen in Figure 5.1.

Figure 5.1: Three Water Tanks at Red Thistle Ranch

# Chapter 6

# Social Good

This system is able to provide an automated water management system or a water monitoring system to rural farms at a low cost. Many farms are not able to afford systems due to their high cost, power requirements, or communication restrictions. Other systems use mechanical sensors that require the farmer to check the tanks physically. The HA system provides a solution to farmers with the option to be able to have a low cost, robust and reliable water management system. This solution can help to manage, monitor and save on water consumption as well as save time for the farmers as they do not need to perform this task by hand. Each smart tank (SU + AU) costs around US$ 110 in retail off-the-shelf components with the prices and components of the SU and AU shown in Table 6.1. When using the full system, the Base Staion costs around US$65 while the RU costs around US$ 57 with the prices of components shown in Table 6.2.

This is also a self sustaining system as it can all be powered through the use of solar panels. Using solar panels makes the system more flexible in where is can be installed, as it does not require hard line power in order to work. This along with LoRa radios enables it to be installed in rural areas where distances between tanks can be long.

| SU Components | Price (US$) | AU Components | Price (US$) |
|---|---|---|---|
| Whipser Node | $30.07 | Wires | $0.50 |
| PCB | $0.10 | Plastic Water Solenoid Valve | $13.47 |
| Antenna | $6.03 | Power Source (wall adapter) | $11.98 |
| SMA female edge connector | $1.22 | Relay | $12.29 |
| Ultrasonic Sensor | $3.71 | | |
| Wires | $0.50 | | |
| Standoff Header Pins | $0.25 | | |
| RTC | $8.73 | | |
| Solar Pannel | $1.00 | | |
| Battery | $7.00 | | |
| Casing | $2.27 | | |
| Temp/Hum Sensor | $2.10 | | |
| Charge Controller | $0.60 | | |
| MicroSD card module | $1.40 | | |
| MicroSD card | $8.99 | | |
| **Total** | $73.97 | **Total** | $38.24 |

Table 6.1: SU and AU components broken down by price (USD)

| RU Components | Price (US$) | Base Station Components | Price (US$) |
|---|---|---|---|
| Whipser Node | $30.07 | Whipser Node | $30.07 |
| PCB | $0.10 | PCB | $0.10 |
| Antenna | $5.35 | Antenna | $6.03 |
| SMA female edge connector | $1.22 | SMA female edge connector | $1.22 |
| Wires | $0.50 | Wires | $0.50 |
| Standoff header pins | $0.25 | Standoff header pins | $0.25 |
| RTC | $8.73 | RTC | $7.63 |
| Solar Pannel | $1.00 | Solar Pannel | $5.00 |
| Battery | $7.00 | Battery | $7.00 |
| Casing | $2.27 | Communication | $6.95 |
| Charge Controller | $0.60 | Charge Controller | $0.60 |
| **Total** | $57.09 | **Total** | $65.35 |

Table 6.2: RU and Base Station components broken down by price (USD)

# Chapter 7

# Future Work

This sections looks at improvements for the AU and overall HA system. Most of the future work and improvements of the HA system can be found in [7].

## 7.1 Water Flow Sensor

During testing the flow rate of the hose was known and could be used to calculate the time it would take to refill the tank. In a field test it would be ideal to know the flow rate of the pipe beforehand but this is not always possible. A solution to this would be to connect a water flow sensor to the pipe that the valve controls and use it to calculate the flow rate in order to get a more accurate timing of how long the valve should stay open for. The SU would use the reading from the flow sensor to calculate the water flow and use that to determine for how long to open the valve.

## 7.2 Battery Charge Regulatory Policy

The SU's and RU's current designs do not include a battery charging regulatory policy and charges the battery to its full capacity. Recent studies have shown that battery lifetime can be extended by avoiding full-battery charge cycles [31]. More testing is still necessary to see how the SU's or RU's battery is effected in the long run.

## 7.3 Remote Bootloader over LoRa

Since the SUs and RUs are installed in remote rural locations, it is not the easiest task to manually reset one in case of a software glitch nor to update the firmware when updates are available. Therefore, a remote option for rebooting the micro-controller firmware is essential for agricultural and aquacultural applications to reduce the amount of truck roll necessary. Furthermore, since SUs and RUs only contain LoRa connectivity through ÂB, a custom bootloader over LoRa that utilizes ÂB packages is needed and thus under development.

## 7.4 Custom Printed Circuit Board (PCB)

In order to streamline and standardize the production of the SUs and RUs, a custom Printed Circuit Board (PCB) is necessary and well overdue. A custom PCB will substantially reduce the points of failure as well as soldering time.

## 7.5 Security

IoT devices are in need of security similar just like all internetworked devices. The security measures must protect the hardware, software, and communication channels.

### 7.5.1 Physical

Even though the SUs, AUs, or RUs are not expensive devices, they can still be stolen or vandalized. To prevent the theft of these devices as a whole, they can be secured into place using tamper proof brackets and bolts. To prevent the circuitry from being vandalized or altered, tamper proof bolts and lid opening warning systems in the form of time stamped messages to the base station can be utilized, respectively. Also, tamper proof stickers can be added to the opening of the devices casing so any unauthorized access to the internals of the devices can be detected, at least after the fact.

### 7.5.2 Software

The SU or RU tampering detection message to the base station can easily be used as a means for potential software tampering and can thus initiate a backup, bootloading, or even disabling of the node until it is checked and reconfigured. Furthermore, the SU or RU can be programmed to not allow any direct connections, and hence updates, without proper authentication credentials.

### 7.5.3 Communication

All SUs must be preregistered with the base station prior to deployment into the field. If an SU is not registered, then its request for assignment to the Base Station is ignored; and hence, it will not be included in the RUs' responsibility table, as described in the ÂB protocol [9]. Furthermore, to protect the base station from being manually jeopardized to allow the malicious node onto the network, the usage of blockchain for the storage of all registered network nodes is under consideration and research.

# Chapter 8

# Conclusion

This dissertation introduces an implementation of the HA smart tank, more specifically the AU component of the bigger HA system. Combining the AU system with improvements to the SU system creates the HA smart tank. The smart tank system is able to communicate with RUs or the Base Station allowing it to be integrated into the HA system. An AU portion of a HA smart tank can either be controlled by a single SU or multiple AUs can be controlled by the Base Station. This system helps small or rural farms be able to afford an automated water management and monitoring system which will help them save water, time and money. The HA system will be installed at Red Thistle Ranch to show the robustness, usability and reliability of the system.

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