Increasing Operational Time Efficiency of Monitoring Broadacre Spray Irrigation Systems

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Abstract

This design portfolio looks at a potential implementation for a remote monitoring system that is based upon a Beaglebone system and multiple wireless communication technologies so that data can be transferred quickly and effectively whilst being a reliable system.

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Figure 1: Linear Move Irrigation System

1 Background

Linear moves are a form of spray irrigation that is used to water large rectangular paddocks in a farming environment. They are electro-mechanical systems that rely on a generator and pump to move water from a channel to sprays above a crop which are propelled using electric motors up and down a paddock. (Figure 1) They are controlled by a control panel that sits at the engine and pumping platform, which controls the speed of the end towers of the machine, which determines the overall speed of the machine and application of water.

Linear moves are usually reliable, however they can occasionally develop subtle problems which forces operators to monitor their progress throughout their operation. Some issues that develop can result in the linear move being shut down for no apparent reason, and need to be restarted manually to continue irrigating the paddock. Other issues can include electrical failures that cause the machine to not move, and over-water a section of a paddock, which can cause a loss of crop productivity in that area. Mechanical failures such as towers becoming bogged are also possible, and need to be monitored, to ensure that the system is running as it is required to be. These issues force a linear move to be monitored during their operation, to ensure that if an issue does occur, it is able to be resolved quickly so that the paddock does not fall behind on its watering schedule, and that the properties channels do not overflow, as water is not being removed from them at the end if a linear is not operating.

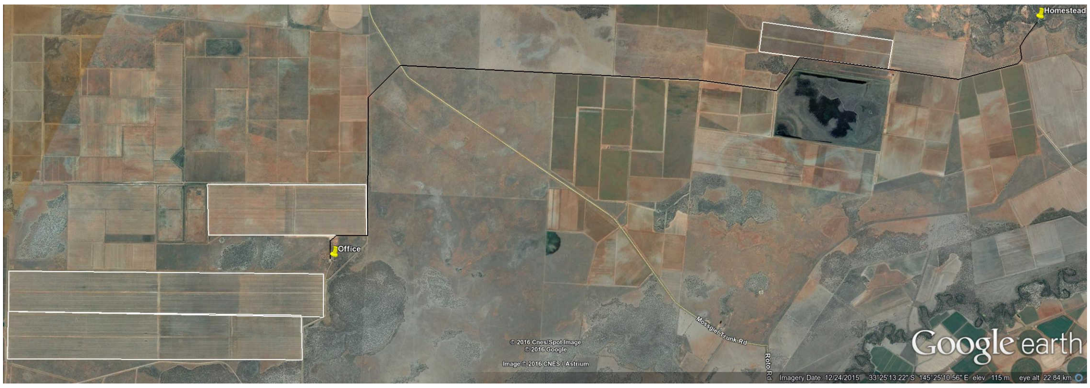

Figure 2: Merrowie/Brooklyn Linear Move Irrigator Locations

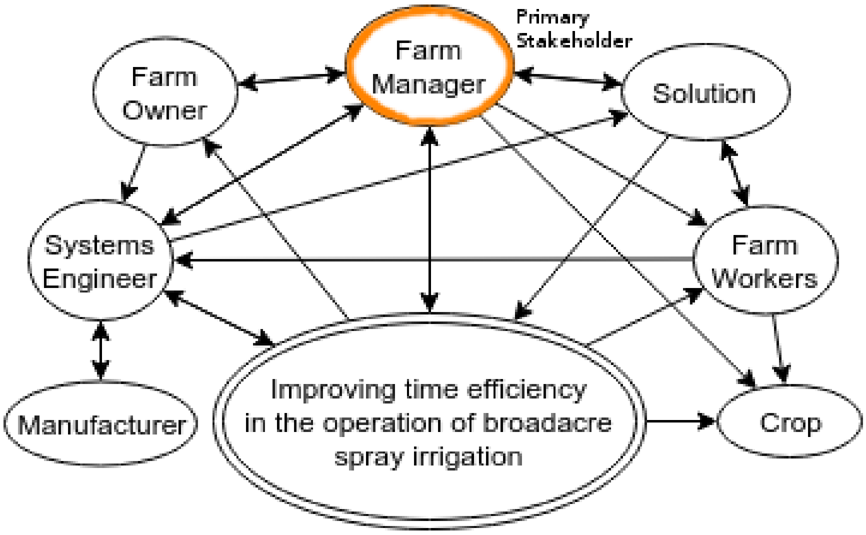

Figure 3: Stakeholder Analysis Map

2 Client

This project was undertaken for Mr. Rob Collins, the Farm manager for the properties Merrowie and Brooklyn owned by Twynam Pastoral Company in relation to the 4 Linear move irrigation systems (Figure 2) located on these properties. Due to more extreme weather patterns in the area during summer, the use of these linear moves has increased dramatically, and due to the large distances between these irrigators, the amount of time spent travelling between them to ensure that they are running correctly has increased. While the main focus of this report will be around Mr. Collins, it is important to recognise the people that work around him in relation to the farm, who will also be affected by any implemented system (Figure 3).

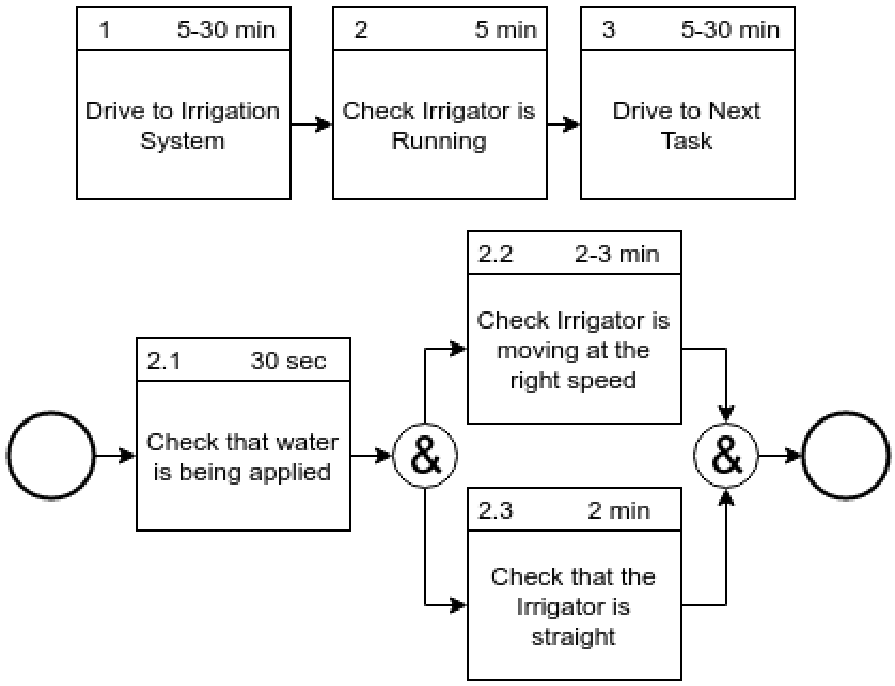

Figure 4: Logical Flow Diagram for Monitoring an Irrigation System

Currently, the linear moves are monitored in person by having someone drive to the linear move to ensure that it is working correctly by watching its operation to ensure that it is moving and water is being applied to the crop (Figure 4). This process can take a significant amount of time, as Merrowie/Brooklyn is a very large property (Figure 2), (25 km from the homestead to the office), which is traversed from end to end in order to ensure that the linear moves are running correctly, particularly overnight, which results in a round trip that takes up to 45 min (depending on what linear moves are running) to ensure that they are operating correctly. The full length (25 km) trip can be undertaken every evening if the weather is very hot over the summer period, to ensure that the crop yields are high enough. Reducing the necessity to undertake this journey at night, and smaller journeys throughout the day reduces the amount of fuel that is used on the farm, improves safety due to lower dark driving hours and improves his productivity by reducing the time taken to complete this task. (Collins, 2016)

3 Limitations of Existing Solutions

In an interview with my client and an expert in the field, the prevalence of existing remote monitoring and management systems was brought up, however these were not considered appropriate solutions. The existing solutions are usually proprietary to a single brand of linear, due to their creation by the manufacturers of a specific linear move system. This is not a problem for many farmers, as they will only have linear moves from one company, however due to the age of this farm, and the past expansion of the property by purchasing neighbouring land with existing linear move systems, there is a variety of systems present on this farm. These solutions can also be hard to maintain, as they were designed for use in the USA, and build off technologies that are appropriate for that environment, and are difficult to adapt to the Australian environment. Other systems that are easier to maintain often rely on outdated technologies which can be inconvenient to use, such as UHF based systems, which can be difficult to use due to limited communication methods (only audio), and are able to be interfered with due to UHF's insecure nature, or be an annoyance to other people listening into the UHF signals that are broadcast. (Collins, 2016) (Rowlands, 2016)

The prominent existing solutions for remote monitoring and control of these irrigation systems are proprietary, and are primarily designed for the US market, which reduces their appeal for Merrowie/Brooklyn. Merrowie/Brooklyn is a very large property with mixed irrigation equipment, so implementing a proprietary monitoring and control system would require an expensive compatibility layer between the irrigation system and the remote monitoring and control system, or replacing the entire control system with a compatible one (Valleyirrigation.com, 2016) (Rowlands, 2016). Due to the variety of equipment across these linear move irrigators, this would increase the costs of implementing one of these existing systems dramatically compared to a more flexible platform. A more flexible platform would also allow monitoring of many different parameters of the system that may be unsupported, such as imagery from cameras to check alignment, or to determine what the cause of a shutdown of the system was. (Rowlands, 2016)

4 Scope of Solution

The scope of the investigated solution only covers the remote monitoring and control equipment. Any other components that are required to communicate with this device are not dealt with in this project due to time and space constraints, however a complete and implementation ready solution will have to have careful thought and research put into these areas. The design of the implemented solution should be able to be as expandable as possible to ensure that the expectations of the client are met, and can be implemented without large changes to the physical implementation of the remote remote monitoring equipment.

5 Requirements

For a proposed solution, the stakeholders require a system that is going to save them money by reducing the amount of time that is spent driving to and from the system for any reason. This requires that it is reliable, so it can be trusted to operate correctly, without forcing time to be spent on diagnosing problems or repairing it. Due to the rate of turnover with staff on the property, it's use has to be taught to new workers quickly,

Table 1: Technical Performance Measures

Customer Requirement	Design Requirement	Metric	Ideal Value
Displays Useful Data	Multiple Inputs	Integer	∞
Multiple Users	Multi-User Interface	Yes/No	Yes
Reliable	Uptime	%	100%
	Standby Time	Weeks	∞
Affordable	Time Saved	hours / year	+ve
	Upfront Cost	$	$ 0
	Maintenance Cost	$ / year	$ 0 / year
Long-Lasting	MTM*	years	∞
Flexible	Systems Compatible	Integer	∞
Ease of Use	Time to Learn	hours	0

* Mean Time to Maintenance for the implemented solution

and they need to be able to access the data that is collected by the monitoring system. (Collins, 2016)

In discussions with the primary stakeholder, and other stakeholders involved with the operation and maintenance of this equipment, a list of requirements was put together that need to have a balance found between them. These are described in Table 1 as the requirements given by the customer translated into design requirements as Technical Performance Measures (TPMs).

The importance of these requirements were ranked using techniques which are not shown here due to space constraints, however they were ranked as follows:

1. Time Saved
2. Maintenance Cost
3. Systems Compatible
4. Uptime
5. Mean time to Maintenance
6. Multiple Inputs
7. Standby Time
8. Multi-User Interface
9. Upfront Cost
10. Time to Learn

(Collins, 2016), (Rowlands, 2016)

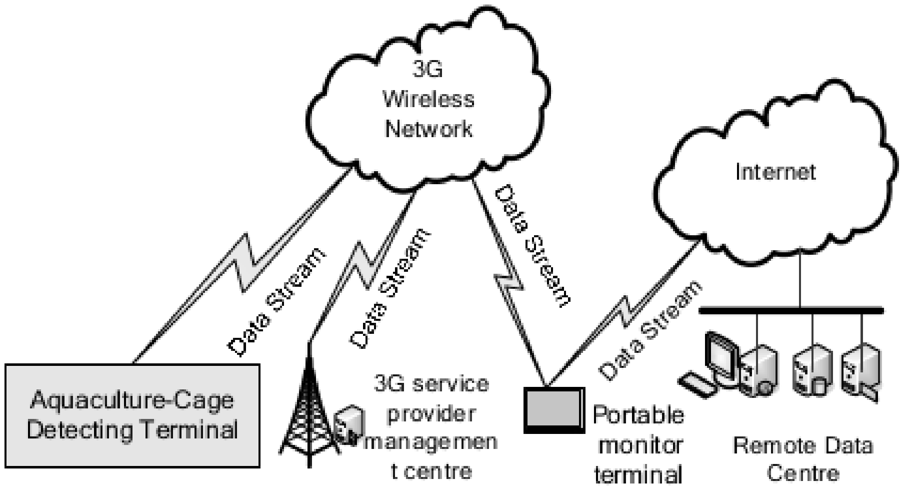

Figure 5: Monitoring System Structure (Wang, Qi and Pan, 2012)

6 Remote Monitoring Methods

Recently, due to the widespread availability of small internet connected devices, a lot of research has been done on remote monitoring solutions for many different applications. The most common platform that has been used are small ARM devices that collect data from various sensors and are connected to a server through a network link in order to facilitate data transfer. This uplink allows the ARM device to communicate with a device that either stores the information, or displays it to an end user. (Wang, Qi and Pan, 2012). This can allow for real-time remote monitoring of equipment and environments, as well as redundant storage on a device that allows for archives of past data to be stored and analysed (Figure 5). Utilising a server to store and analyse data allows issues that manifest themselves in long term trends to become apparent, as an instantaneous view may not be able to pick up what issues may be manifesting within the machinery in the long term. this process allows important information about small problems to be found which may manifest themselves in future major problems (Li et al., 2011). This analysis is able to be stored remotely even when the data is not being accessed, allowing the analysis to take place in real time so that problems can be detected as soon as possible (Figure 6. These particular monitoring solutions that have been implemented will serve to guide the design of the final solution, in terms of system architecture and component selection.

7 Solution Design

In order to fulfil the requirements outlined in Table 1, it is important to find a overarching design on which to build the solution around (Figure 7). This allows components to be selected that are able to interface with each other so that the

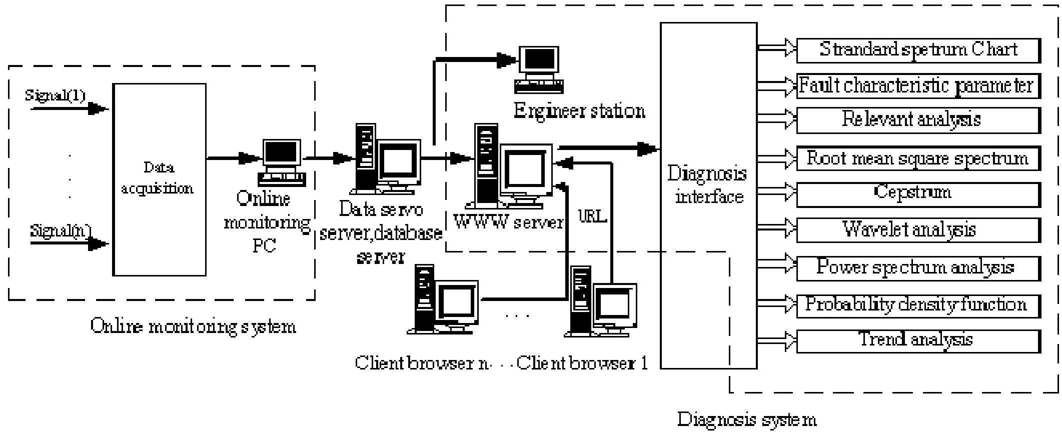

Figure 6: Remote Data Analysis (Li et al., 2011)

best combination of parts can be found in order to fulfil the system's requirements. In order to find the best solution, each component should be selected individually, considering how it interfaces with the other devices, and be compared to other devices that carry out the same role.

In the proposed solution design (Figure 7), the subsystems that are covered in this report will be the parts that are mounted to the irrigation machine in order to monitor and control it. This is the most important aspect of the system, and the other subsystems are able to be built around what is recommended in this report. This means that the Monitoring, Communications, Control and Backup Power subsystems will be looked at in depth. These systems require an overarching controller or computing platform, which is not shown in the system architecture diagram, however it is the interface between the systems located at the machine. The monitoring and control systems by nature will be simple electromechanical systems that feed data into and take commands from the computing platform, and the communications subsystem will connect to the computing platform to transmit data to the management system. Through research into compute platforms, communication methods and backup power, the possible options in Figure 8 were looked at.

8 Component Selection

In order to select the correct components for the remote monitoring system, the main components have to be looked at compared to other devices that could fulfil a similar role within the system. This allows potential solutions to be looked at critically, facilitating the choosing of the most appropriate components for a final design. Potential components should be looked at in relation to their performance against the TPMs in Table 1, and compatibility with the other components within the system.

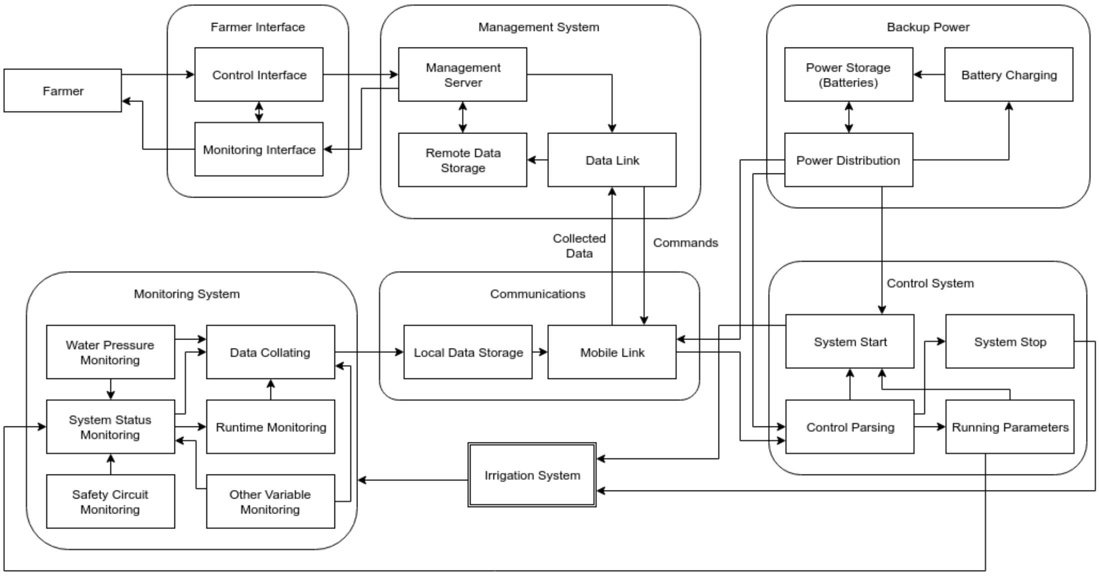

Figure 7: System Architecture of Solution

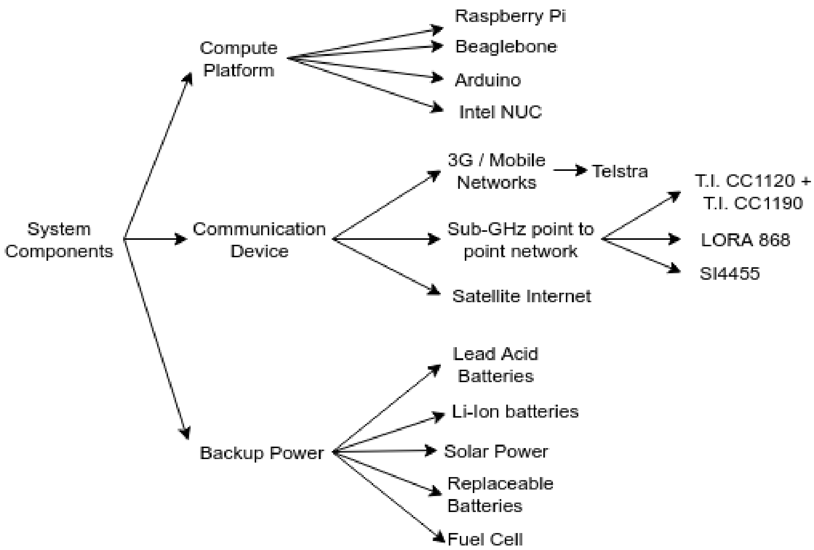

Figure 8: Potential Component Selections

8.1 Compute Platform

The compute platform is an integral part of the monitoring system, as it ties together the other subsystems as the interface between them. This pervasiveness of the compute platform links it closely with the other subsystems, and has the greatest impact on the overall reliability of the system. Through online research, the most suitable freely available platforms are the Raspberry Pi, BeagleBone, Arduino and Intel NUC. Each of these platforms has a variety of options with regards to specific devices, however most of the TPMs are able to be compared to the overall platform, rather than the individual devices. It is useful to look at these platforms in terms of their intended purpose, as their design differs significantly because of this, preventing a fair comparison between specifications. (Beagleboard.org, 2016).

The Intel NUC platform is designed to be a complete computer, and would be able to handle a large amount of data storage and communications due to this. It would allow long term data trends to be analysed and give insight into the performance and operation of the machine on-site. This data would be able to be accessed remotely very easily with a fast data connection. However it requires a large amount of power to run compared to the other platforms that are looked at, and it lacks the large number of General Purpose Input Output pins of the other platforms, that are required for connecting assorted sensors. (Intel, 2016)

At the opposite end of the spectrum, the Arduino platform has very low processing and communication capabilities. Despite this, it would still be possible to create an implementation around this at the expense of reducing the number and complexity of monitored systems. (Arduino.cc, 2016)

The Beaglebone platform and Raspberry Pi platform are similar in that they share a middle-ground between the Arduino and Intel NUC platforms, as they have more processing capability, but are not designed to be a complete computer as the Intel NUC is. They are designed to act as capable computers, however they are more bare, and have the ability to connect sensors directly to a large number of GPIO pins, which the Intel NUC lacks. Their differences lie in the tradeoff between I/O capabilities and their usefulness as a general computer platform, as the Raspberry Pi has a greater emphasis on being a "Computer the size of a credit card", whereas the BeagleBone is designed to have a greater focus on industrial control and communications capability. In this situation, the Beaglebone is more useful than the Raspberry Pi, due to the emphasis on I/O capabilities over general use, allowing a larger number of sensors and communication devices to be connected. (Beagleboard.org, 2016)(Make: DIY Projects and Ideas for Makers, 2014)(Raspberry Pi, 2016)

Comparing the BeagleBone platform to the Arduino and NUC platforms, the BeagleBone appears to be the most capable platform due to the combination of processing capability and I/O, as well as being a middle-ground between the others for most metrics. This allows the BeagleBone to be a very well rounded platform for what we require, and will allow it to interface with any sensors that may be required.

Table 2: Comparison of Communication Methods

	Running Costs	Initial Cost	Range	Power Ranking
Mobile Networks	$50 / year	$70	N/A	4
Satellite Internet	>$20 / month	Unknown	N/A	5
T.I. CC1120	<$10 / month	<$20	100km (LoS)	1
LORA868	<$10 / month	$120	21km (LoS)	3
SI4455	<$10 / month	<$20	20-100km ?	2

8.2 Communication Methods

As shown in Table 2, the most effective communications method is the combination of Texas Instruments CC1120 Transceiver and CC1190 Signal booster. These components are designed to work together, which prevents any technical difficulties between these components. This requires that a base station be set up, likely at the Office of Merrowie/Brooklyn (Figure 2), in order to connect the system to the internet. It may also be possible to have a secondary data connection that can be toggled to send more detailed information, most likely through a mobile network, which has the highest throughput per price, when compared to the other high throughput solution, satellite internet, which is far more expensive. This would allow a more dense information stream to be transmitted such as photo or video when required, without reducing standby time dramatically, as it is not active all the time. A clear outlier in terms of cost is Satellite Internet, where it was anticipated that there would be low cost solutions, however nothing effective was found. The Running costs relating to the Sub-GHz radio equipment would be put down to power costs of the base-station, and its internet use from the base-station, whereas the running costs for mobile networks and satellite internet are based on subscriber fees.

8.3 Backup Power

According to the TPMs (Table 1), a low maintenance cost is desired. This reduces the appeal of replaceable batteries that are non-rechargeable and fuel cells due to their ongoing costs that are associated with keeping it running. This reduces the viable solutions to Lead-acid or lithium batteries and solar power. Looking at these solutions shows that a solution based off a Lead-acid or lithium-ion battery is required, and solar power is an optional addition to the system. Comparing Lead-acid batteries with lithium batteries shows that whilst the initial cost of the system is much higher for a lithium-ion battery, the ongoing costs associated with lead-acid batteries due to a shorter lifespan, diminish this advantage. The ongoing costs as well as the higher energy density of lithium batteries make it the better choice for this system.

The addition of a solar panel, whilst increasing the initial cost of the solution improves the uptime of the system. This trade-off is very positive due to the rankings of the TPMs (Table 1), as uptime is a much more important requirement than a low initial cost. The addition of a solar panel also reduces the long term maintenance costs by preventing the Lithium battery from discharging completely, a process that severely shortens its lifespan. These factors show that the inclusion of a solar panel to charge the backup battery is important to the overall design.

9 Solution

The presented solution provides a base platform for sensors and monitoring equipment to be attached to. This flexibility allows the large number of sensors required by the TPM's (Table 1) as well as the generic nature to allow it to connect to many different models of irrigation control systems. It relies on a Beaglebone board that communicates with a server through a sub 1GHz radio to a base station that is connected to the internet, as well as a secondary high bandwidth communication channel through mobile networks if required. These are able to be managed by the Beaglebone in order to process incoming data from sensors and incoming commands from elsewhere. This combination of base devices has been shown to be the best fit for the TPMs, allowing a cohesive system to both remotely control and monitor an irrigation system.

10 Further work

In order to fully implement a working system, considerations of human interaction, and communications at the other end of the system have to be considered. Until this work is completed, a fully operational system is unable to be implemented, however currently, a solution for the remote side of the system, one of the more challenging aspects of the design has been completed. Ideally, at the end of any further work, The interaction shown in Figure 9 should be able to take place easily.

Further investigation also needs to be carried out in order to determine how the data is going to be stored and retrieved remotely, if at all, as well as communication protocols between the monitoring system and the client. This needs to take into consideration the uptime of a remote server, the costs associated with it, and how it should be run, whether it becomes servitized for use by multiple farm managers in similar positions, or are run on a farm by farm basis. This also requires that the servers have access control implemented so that only the necessary people have access to data and control about the monitored and controlled systems.

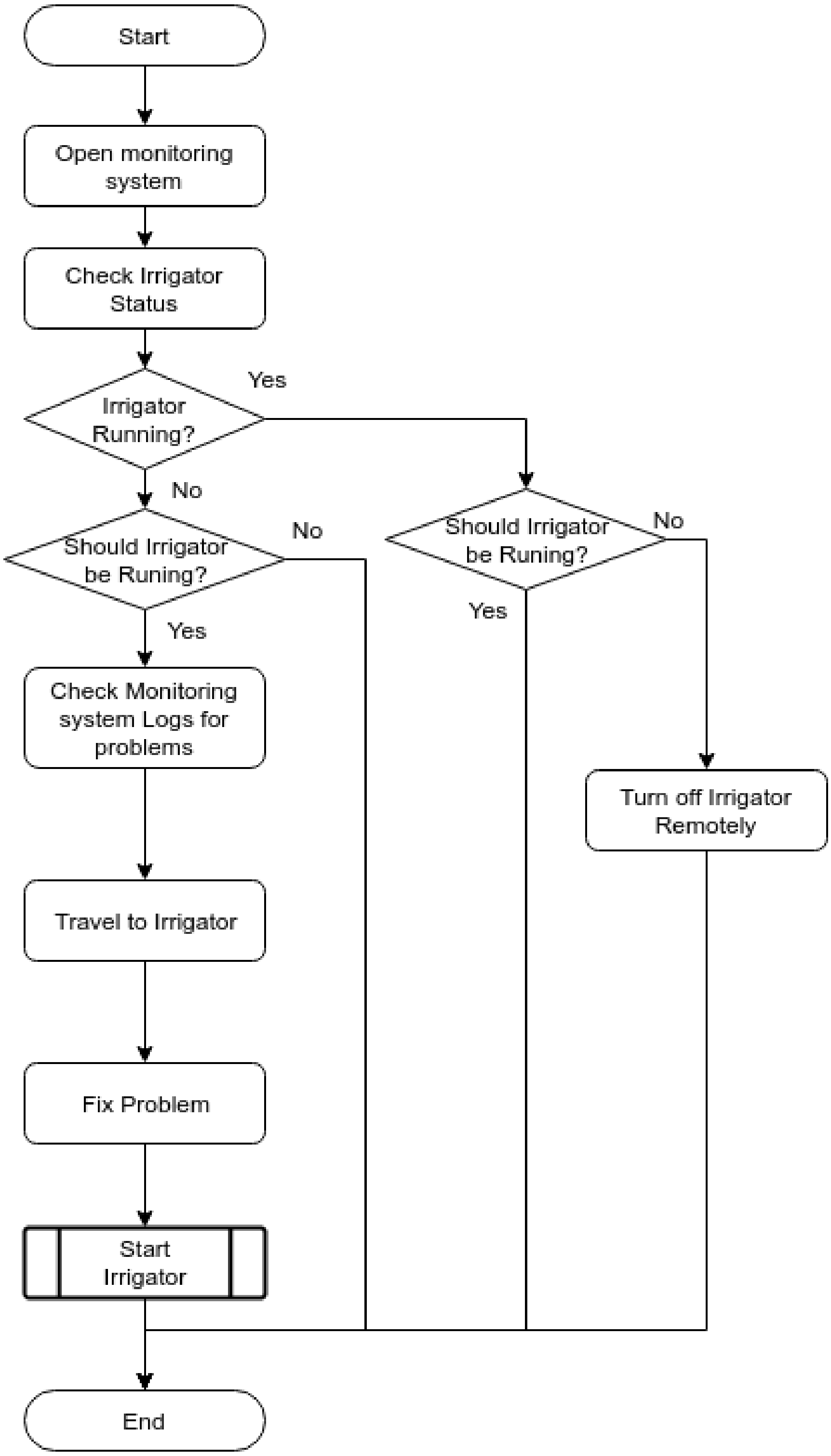

Figure 9: Basic Interaction with Implemented Solution

11 Reflection

Throughout this design process, I recognised the difficulties in reconciling my preconceived notions regarding the problems that would have to be addressed through the design process, and the actual data that had to be looked at. I had come into this assignment with a pretty good idea of how this system would be implemented, however it turned out that many of the preconceived ideas that I had were incomplete and had not been considered properly. Going through an analysis of potential solutions was very helpful, comparing them to the Technical Performance Measures, and doing desktop research into the original specifications and intended design of potential components that would come together to form a solution.

Organising my thoughts for potential components through structured brainstorming was also very useful. It allowed me to collate my many different ideas for potential implementations of the system at different times, then group them so that they could be compared against other similar components within the system. This gave a more well thought out solution to the problems that were encountered, rather than taking a single idea and running with it throughout the portfolio as in my draft.

Through the peer review process I received a variety of conflicting criticisms and praise for my draft portfolio. It was difficult to determine which suggestions would be helpful and which ones were not so due to their nature, however it was clear that some of the reviewers did not understand the ideal outcomes for this assignment and were critical of the fact that the rigid 'design process' was not followed through the spiral that was presented in lectures. This helped me invalidate a lot of their criticisms, even though some of them may be very valid, it made it difficult to recognise some criticisms that may still be valid, which were ruled out due to this.

Considering the peer review process from a peer-reviewers end, it would have been helpful to view a design portfolio that was of a high standard, however I received two portfolios to review that were of a low standard, and was unable to learn much from critiquing them directly. It would have been more beneficial to have received portfolios that were of both high and low standards in order to take a critical view of one, to provide feedback, and learn from a more well thought through portfolio to gather ideas for my own, as well as being able to look more in depth at potential problems rather than be overwhelmed by very obvious issues.

12 References

References

Altenergymag.com. (2016). A Comparison of Lead Acid to Lithium-ion in Stationary Storage Applications. [online]Available at: http://www.altenergymag.com/content.php?post_ type=1884 [Accessed 13 May 2016].

Arduino.cc. (2016). Arduino - ArduinoMKR1000. [online]Available at: https://www.arduino.cc/en/Main/ArduinoMKR1000# techspecs [Accessed 13 May 2016].

Beagleboard.org. (2016). BeagleBoard.org - 2015-02-05-raspberry-pi-2. [online] Available at: https://beagleboard.org/blog/2015-02-05-raspberry-pi-2/ [Accessed 13 May 2016].

CC1120 High-Performance RF Transceiver for Narrowband Systems. (2016). 1st ed. [ebook]Texas Instruments. Available at: http://www.ti.com/lit/ds/symlink/cc1120.pdf [Accessed 13 May 2016].

Collins, R. (2016). Operation of Linear move Systems.

Cooking-hacks.com. (2016). Extreme Range Links: LoRa 868 / 900MHz SX1272 Module for Arduino, Waspmote and Raspberry Pi. [online]Available at: https://www.cooking-hacks.com/documentation/tutorials/extreme-range-lora-sx1272-module-shield-arduino-raspberry-pi-intel-galileo/# step9 [Accessed 13 May 2016].

Intel. (2016). Mini PC: Intel NUC Kit. [online]Available at: http://www.intel.com.au/content/www/au/en/nuc/nuc-kit-de3815tykhe-board-de3815tybe.html [Accessed 13 May 2016].

Li, G., Kong, J., Jiang, G., Xie, L., Xiao, H., Wu, Z. and Xu, S. (2011). Remote monitoring and diagnosis system of rolling mill based on CORBA and SOAP/Web service technology. Noise & Vibration Worldwide, 42(10), pp.23-27.

Li, H., Wang, H., Yin, W., Li, Y., Qian, Y. and Hu, F. (2015). Development of a Remote Monitoring System for Henhouse Environment Based on IoT Technology. Future Internet, 7(3), pp.329-341.

Make: DIY Projects and Ideas for Makers. (2014). How to Choose Between Raspberry Pi and BeagleBone Black — Make. [online]Available at: http://makezine.com/2014/02/25/how-to-choose-the-right-platform-raspberry-pi-or-beaglebone-black/ [Accessed 13 May 2016].

Raspberry Pi. (2016). What is a Raspberry Pi?. [online]
Available at: https://www.raspberrypi.org/help/what-is-a-raspberry-pi/ [Accessed 2 May 2016].

Rowlands, R. (2016). Analysing Remote Monitoring Systems.

SI4455 Data Short. (2016). 1st ed. [ebook]Silicon Labs. Available at: http://www.silabs.com/Support%20Documents/TechnicalDocs/Si4455-short.pdf [Accessed 13 May 2016].

Staff, E. (2016). The Use of Lithium-Ion Batteries in Uninterruptible Power Supplies — Battery Power Magazine. [online]Batterypoweronline.com. Available at: http://www.batterypoweronline.com/main/markets/batteries/the-use-of-lithium-ion-batteries-in-uninterruptible-power-supplies/ [Accessed 13 May 2016].

Touhami, O., Sadoun, R., Belouchrani, A., Hamdani, S., Boukoucha, A. and Ouaged, S. (2013). Remote monitoring system of electrical machines via INTERNET. 2013 9th IEEE International Symposium on Diagnostics for Electric Machines, Power Electronics and Drives (SDEMPED), pp.23-27.

Valleyirrigation.com. (2016). BaseStation3 Remote Control and Monitoring Solution — Valley Irrigation. [online]Available at: http://www.valleyirrigation.com/valley-irrigation/us/control-technology/basestation3 [Accessed 13 May 2016].

Valmont, (2016). Valley Basestation v3 User Guide. 1st ed. [ebook]Valmont Industries Inc. Available at: http://az276019.vo.msecnd.net/valmontstaging/docs/default-source/irrigation—owners-manuals/english—intl/0999302_ a.pdf?sfvrsn=6 [Accessed 26 Apr. 2016].

Wang, Y., Qi, C. and Pan, H. (2012). Design of Remote Monitoring System for Aquaculture Cages Based on 3G Networks and ARM-Android Embedded System. Procedia Engineering, 29, pp.79-83.