**FarmMD**

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| A Project Report Presented to  The Faculty of the College of Engineering |
| San Jose State University In Partial Fulfillment Of the Requirements for the Degree **Master of Science in Software Engineering** |

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| By |
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ABSTRACT

**FarmMD**

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Today the world is battling with the drought condition. To secure our future, we need ways to conserve the water in our daily life. Growers, be they agricultural, institutional or residential, consume a substantial amount of water and power resources every single day for irrigation. Efficient irrigation depends on upon many factors like weather conditions, soil pH, salinity, moisture, temperature and plant type. Close to 50% of water used outdoors is wasted due to inefficient resource management.

There are many existing systems which ensure efficient water and energy consumptions for irrigation, but these systems have many inherent problems. One issue is that most systems are hard-wired communications networks creating installation difficulties.

Growers also need systems that will have continual connectivity and eliminate any security breach. Another problem is no current system is designed to provide the number of the sensors required for adequate, instantaneous readings for moisture, pH, and salinity for agriculture, institutional and residential horticultural needs.

In this project, we aim to develop a sensor system which will provide a secure network while taking intelligent decisions to maintain the irrigation schedule that saves the water and energy. The end user can monitor functionalities of the system from anywhere. It provides the graphical representation of the resources used and saved over a period of time including details of the soil pH level, salinity, and moisture. Our work will help growers choose judicious watering schedules, suitable plants and fertilizers for the soil which leads to increase in harvest and greater awareness about their cultivation.

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# Project Overview

## Introduction

## Proposed Areas of Study and Academic Contribution

## Current State of the Art

# Project Architecture

## Introduction

Include introductory text text plus a diagram.

## Architecture Subsystems

Describe major subsystems in your architecture.

# Technology Descriptions

Assume you audience is a skilled computer scientist that has some familiarity with technologies taught in the client/server program. The topics below are for a typical MS Software Engineering project. Adjust the topics in this chapter to meet the needs of your project.

## Client Technologies

## Middle-Tier Technologies

## Data-Tier Technologies

# Project Design

Add additional chapters if necessary to keep chapters at a reasonable length. This chapter should describe the important design elements of your project. Describe elements that are key to project and that are innovative. The topics below are for a typical MS Software Engineering project. Adjust the topics in this chapter to meet the needs of your project.

## Client Design

Include screen shots to illustrate your application plus UML diagrams to illustrate your programming design.

## Middle-Tier Design

Include UML diagrams describe your middle-tier components.

## Data-Tier Design

Include database schemas and other data elements important to your project.

# Project Implementation

The FarmMD project being an IOT project has several components such as the hardware, middleware and the application software that make up the system. In order to plan, implement and deploy such a system we have followed the agile development methodology.

## Project implementation scope

The system has several interrelated components that come together to form a robust architecture. FarmMD is an agricultural IOT system that has several tiers such as the Hardware, Middleware and the Application Front-End.

## Client Implementation

* Hardware

The hardware consists of sensors and gateway that connects to WiFi. These are built together to collect data from the atmosphere and soil, and sent to the database.

**Sensors**: The sensors are used to determine atmospheric conditions. Below are some of the sensors used in our system.

* + Temperature Sensor
  + Moisture Sensor
  + Humidity sensor
  + Salinity sensor

**Gateway:** LoRa Nano-Gateway is a WAN solution that provides kilo-meters of range while consuming very low power. This makes it very suitable for IOT. This is used to set up a network. The LoRa network consists of devices, gateway, network and an application.

* Mobile App

The Mobile application for the project is developed in Android OS. The mobile application is used to register a new device by reading QRCode. It is also used to view alerts from the system and take voice commands to perform action. Through the mobile application, the system settings can be customized as needed.

* Web Application

The Web Application provides the user interface for the User and Administrators to interact with the system. It is developed using, Node.js, Express.js and Angular.js. It provides user options to customize the system based on the user’s requirement. It also displays the sensor readings as graphs and charts by fetching the sensor data stored in the Cloudant database and visualizes the data as charts. This helps give the user a better understanding of the data.

The application also provides notifications and warnings according to the settings defined to the registered recipients.

* API

The system also provides API for fetching data and analyzed decisions from the system. This can be used by 3rd party devices to fetch data and watering decisions.

## Middle-Tier Implementation

The middleware tier is responsible for collecting data from gateway and sending it to the Cloudant database.

Using CURL library in C, an application is designed to send data to the Cloudant noSQL Database directly from the gateway. This has been developed from scratch as there was no documentation available to send data from the LoRa-Nano gateway directly to the cloud.

**Node-red** API has been developed to consume data from the cloud and make it available for web and mobile applications.

## Data-Tier Implementation

* Cloudant noSQL Database

This is a cloud database by IBM where the system’s data resides.

## Implementation methodology

We have followed the Agile Software Development methodology for all the phases of our project development. We have built frequent working versions of our system and worked closely with each other in a team to clearly understand the requirements and deliver suitable solutions for it. We communicate on Slack and have weekly scrum meetings to discuss the progress of our wok. We also maintain to-do lists to be able to track our progress.

## Project implementation issues and resolutions

The working of this project posed multiple challenges on us. Below are some of the challenges that define our project.

* As it is an IOT project, we were supposed to learn to work with hardware and controllers, it was a steep learning curve which eventually taught us a lot about working with low level languages and interfacing with hardware.
* Decision on using suitable gateway technology for our requirement involved us experiment with various different hardware and understand the way they are working.
* Using CURL library in C, application is designed to send data to the Cloudant noSQL Database directly from the gateway. This has been developed from scratch as there was no documentation available to send data from the LoRa- Nano gateway directly to the cloud.
* Working on the web application involved a lot of learning as the application was to be in Angular.js and Node.js.
* As we are working with very new technology, we have not had the privilege of getting much from the internet. We are worked hard to understand everything on our own and with the help and guidance of our project guide.

## Used tools and technologies

We have used a number of emerging technologies in our project. Below are some of the major categories of technologies used.

Hardware and Middleware:

* LoRaWAN : It is a Low Power Wide Area Network (LPWAN) specification for battery operated things in a network. LoRaWAN provides secure bi-directional communication, mobility and localization services. The LoRaWAN specification provides seamless interoperability among smart Things without the need of complex local installations.[15]
* LoRa Nano-Gateway: Is a WAN solution that provides kilo-meters of range while consuming very low power. This makes it very suitable for IOT. This is used to set up a network. The LoRa network consists of devices, gateway, network and an application.
* Sensors such as the temperature, humidity, moisture and salinity.
* Node red: Tool for integrating devices and APIs by IBM

Client Applications:

* Android: Is used for developing the mobile application
* Node.js and Express.js: For developing the backend of the Web Application and for building REST APIs.
* Angular.js, Bootstrap, HTML, CSS, JQuery: For Developing the front end of the Web Application
* Canvas.js: For developing the graphs of the application
* NEXT framework by Cisco is used to show the sensor topology in the web application.
* RESTFul services and JSON: For sending and receiving data to and from the cloud.
* Cloudant NoSQL database: Database that is used to store the sensor data and the system specific information.
* Git and Github for maintaining and collaborate in groups and for tracking.

# Testing and Verification

Describe your test strategy, process, and results for verifying the functionality of your project.

# Performance and Benchmarks

Describe any performance and benchmarking criteria you used for your project. In addition, describe any benchmarking results you observed in your project.

# Deployment, Operations, Maintenance

Describe any deployment strategies, operational needs, and maintenance required for your project.

1. **Deployment**

* The Web Application that is used to interface with the system is deployed on the IBM Bluemix Cloud.
* The API to fetch the data from the cloud is available on IBM Bluemix Cloud Platform.
* The Cloudant database is a cloud database available on the IBM Bluemix Cloud Platform.
* We have 3 different stages for Developing, Staging and Production hence always securing our production.
* We have set up the system for continuous delivery by using continuous integration tools in IBM Bluemix with Git.

1. **Operations**

One of the major aspects of our projects is the Analytics involved in it. Several data intensive operations are performed on the data collected from the sensors and the data from other external operations to make accurate decisions on saving water and optimizing agricultural yield. We are currently working on developing suitable formulas for operations on data.

1. **Maintenance**

In the development of a large project, it is essential to plan the maintenance of the software well in advance. Below are some of the ways in which we are currently maintaining our software and intend to make delta improvements in the future.

* The application code is maintained in a common group github repository which helps keep a track of our changes and the progress that we have made.
* Continuous integration and deployment of application from github reduces efforts in updating changes in multiple locations.
* The common database being using for the application is available on the cloud accessible to all developers.
* We have maintained good coding standards in order to improve its understandability.
* The reports that we have worked on time to time helps in effectively documenting the system.
* We have designed the code to increase efficiency and reusability.

# Summary, Conclusions, and Recommendations

## Summary

‘FarmIoT’ system is providing a unique IoT solution the problem to saving water and energy using ‘LinkLab’ technology. This system also supports huge variety of sensors to provide understanding about soil health. Any grower can access this system via a web application or a mobile application.

## Conclusions

This project was an opportunity to work with fast paced startup in the bay area. As a team, we have learned a lot together starting from requirement gathering till testing phase. This system gave us a good understanding about IoT platform, data analytics and machine learning, web application and mobile frameworks.

## Recommendations for Further Research

* This system can be enhanced to work in the areas where there are network problems.
* Data analytics and machine learning part can be enhanced to give more number of recommendations to the users.
* More number of exciting features can be included in mobile and web application.

Glossary

[1].**IOT** (Internet of things) is a system of interconnected computing devices with unique identifiers that have the ability to connect to the network and send data without human intervention.

**[2]. Artificial Intelligence** is the man made system that is designed to behave in a manner that can be called intelligent.

**[3]. Machine Learning** is a type of Artificial intelligence that provides computers the ability to learn without being explicitly programmed. [3]

**[4]. Linklabs** is a device that provides low-power, wide area network technologies to power Internet of Things.[4]

**[5]. Arduino Due** is a microcontroller board based on the Atmel SAM3X8E ARM Cortex-M3 CPU [5]

**[6]. LPWAN** is a WAN technology specialized for IOT device connectivity with low-bandwidth.

[15]. “Richard Viel,” *LoRa*. [Online]. Available: https://www.lora- alliance.org/What-Is-LoRa/Technology. [Accessed: 06-Mar-2017].

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Appendices