Team Chase Technologies

October 14, 2014

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A1S6

Re: ENSC 305W/440W Functional Specification for Smart Irrigation System

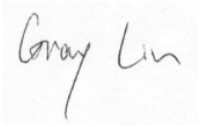
Dear Dr. Rawicz:

Please find the enclosed paper, “Functional Specification for Smart Irrigation System”, which is about the smart control box for automated garden irrigation system designed specifically for the Internet of Things (IOT).

Our smart irrigation system, “C-Sprinkler”, which is able to act independently without complex setup and inputs, and users have options to control the sprinklers remotely and check the past history through the Internet either on the website or mobile app. The C-Sprinkler can break down into four major components: irrigation control unit, environment monitoring device, cloud service and mobile app. The details of function requirement of each component will be provided in this paper. Also this functional specification document will be used as the guideline and reference for our project throughout the entire developing phases.

There are five experienced engineering students in our team: Team Chase Technologies (TCT). If you have any question or concern, please contact me by phone at (778)881-5322 or by email at yuhengl@sfu.ca. I will serve as the contact person for our team. We look forward to your comments and suggestions.

Sincerely,



Gray (Yu Heng) Lin
Chief Executive Officer
Team Chase Technologies

Enclosure: Functional Specification for Smart Irrigation System

Team Chase Technologies

Functional Specification:

Smart Irrigation System

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Executive Summary

In the modern society, people are living in a fast pace and trying to find the way to save more time. Thanks to the developing of technology, nowadays we can spend less time to finish the jobs comparing to what we have done before. Our product, “C-Sprinkler”, is a smart irrigation system use the concept of Internet of Things (IOT), to make people’s life convenient. This system has a control box connected to the sprinklers, it can automatically irrigating based on the plant species, sensor and weather forecast, and it can be remote controlled by end user easily. Using our product, people no longer need to remind themselves if they have irrigated the garden or not, it frees people’s hands and they can put the time they saved towards other things that they are interested.

There are two developing phases for our project. In the first phase we are expecting to build the first prototype including four basic components: control box, sensor, mobile app and server. The first prototype should have following dimensions:

- Manual control on the control box
- Mobile App remote control through cloud server
- Algorithm of calculation based on sensor and weather forecast
- Automated irrigation based on the pre-calculated schedule

The first prototype should meet basic requirement for most features on traditional sprinklers. Also the user should have the ability to take over the control of the system through the control box UI. We are aiming to finish our first prototype in the late November.

In the second phase of the project development, our product will be tested in the real world situation and more functions will be implemented into it such as rescheduling the watering time to meet the local sprinkling regulation and providing irrigation history.

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Glossary

IOT – Internet of Things, IOT is a scenario that objects are capable transferring data to other objects over a network without human interaction [1]

PCB – Printed Circuit Board

LCD – Liquid-Crystal Display

LED – Light-Emitting diode

UI – User Interface

RAM – Random-Access Memory

AI – Artificial Intelligent

OS – Operation System

1. Introduction

The C-sprinkler is a smart irrigation system which has independent AI, remote controllability and cloud service.It has original functions of tradition irrigation system, such as timers and changing directions of sprinkler. Additionally, it can automatically irrigate the garden based on the various information to help users to free their hands and still maintain the garden well even they are away from their home. The requirements for the C-Sprinkler, as proposed by Team Chase Technologies, are described in this functional specification document.

1.1 Scope

This document states the functional requirements that must be implemented into our design of C-Sprinkler. These requirements are prioritized according to the function importance in the different stages throughout the entire development.

1.2 Intended Audience

This document is intended to be used by all members of the Team Chase Technologies, to ensure the design and functional specification meet the expectation throughout the entire project. The CEO shall refer to the functional requirements to measure the developing progress. Hardware/Software engineers shall refer to the requirement while implementing functions. Quality assurance engineers shall refer to the testing section to assist their debugging from small component to the whole system.

1.3 Classification

In this document the following convention will be used to denote the functional requirements:

[R#-P#] A function requirement

R# - Denotes the section number
P# - Denotes the priority of the function requirement

Priority **I** – Feature must be implemented to the proof-of-concept system
Priority **II** – Feature must be implemented to the first prototype
Priority **III** – Feature must be implemented to the final production versions

2. System Overview

General requirement applicable to C-Sprinkler for a complete system are described in the following sections.

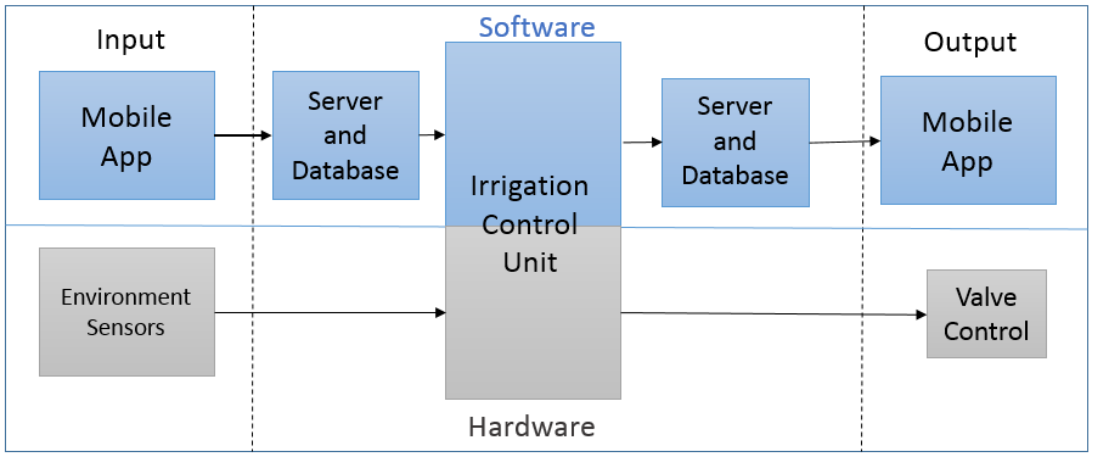

Figure 1: High-Level System Overview

Figure 1 demonstrates the high-level system overview of the design. Columns from left to right shown in diagram represent inputs, signal processing and outputs, respectively. Blocks in blue represent software components and gray represent hardware. The system consists of mainly four parts: mobile app, server/database, irrigation control unit and environment monitoring device.

- **Irrigation control unit -** To collect and process data to schedule irrigation intelligently
- **Environment monitoring device** – Measure environment condition for plants
- **Server and database -** To establish connections between user and control unit, store and provide useful data
- **Mobile app -** Allow users to control the irrigation, view irrigation history and employ other cloud services

Functionalities and requirements of each sub-component will be discussed in respective sections in the article. This section will only introduce functionalities and requirements from point of view of the overall system.

- System should automatically manage irrigation for the plant with basic intelligence
- System should interact with users by providing cloud services through Internet
- System can self-maintain, automatically detect failures and reset parts if necessary
- System should be stable and user friendly: easy to operate and access
- Retail price of setting up the system should be within CAD $200

3. Irrigation Control Unit

This section introduces requirements of the proposed irrigation control unit from three aspects: general, software and hardware. General functionalities and requirements of the control unit that apply to entire system are summarized in section **General Requirement**. Detail standards from software and hardware perspective will be laid out in **Software Requirement** and **Hardware Requirement** respectively. Requirements may possess different priority among proof-of-concept model, prototype and final product model, which will be indicated in content.

3.1 General Requirement

An irrigation control unit must process abilities to receive external request, process incoming data, determine irrigation timing and upload latest information. Functionalities for Proof-of-concept model, prototype and final product are shown below:

[R 1-PI] Default profile contained plant species and soil type for irrigation criteria (cool season turf grass and sandy soils in BC) are stored in the controller

[R 2-PI] The controller powers on the irrigation valve when either the soil moisture reaches the minimum value or an external user request represented

[R 3-PI] Irrigation will be suspended or paused when one of following events occur: high temperature condition, noon to evening, watering restriction period by local regulation and rain forecasts

[R 4-PI] Functionalities of traditional timer irrigation controller must be reserved

[R 5-PI] Users possess highest control authority of the device

[R 6-PI] The controller is able to establish connection to server, download/upload required data (e.g. user request, sensor result, user modification) through the Internet

[R 7-PII] Irrigation duration will be mainly depended on the target moisture throughout the root zoon, but other factors such as current season and soil type will be also considered

[R 8-PII] The controller is able to collect data from soil moisture sensor and temperature sensor

[R 9-PIII] User can override default profile with user preference according to practical situation

The following chat summarise these functionalities,

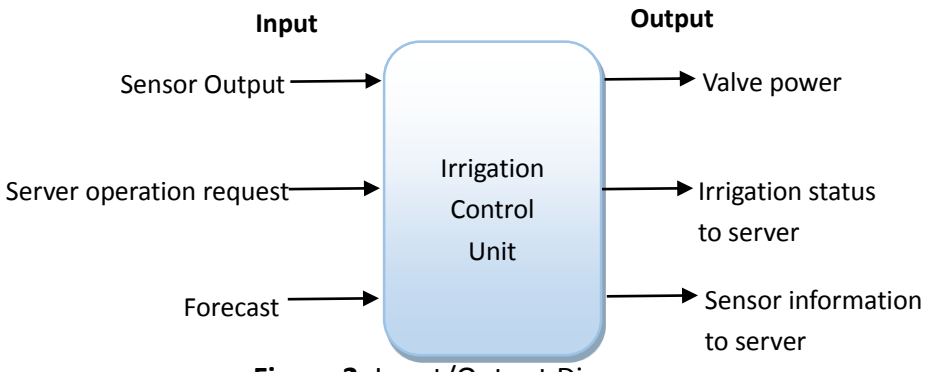

Figure 2: Input/Output Diagram

Other general requirements for irrigation control unit includes,

[R 10-PI] The boot up time of the device should not exceed 1 minute
[R 11-PII] Device should be responsive to each operation request in real time
[R 12-PIII] Cost of the final product should within CAD $150
[R 13-PIII] The device is for indoor use only

3.2 Software Requirement

3.2.1 Operating System Specification

[R 14-PI] The operating system can manage device hardware resources seamlessly
[R 15-PI] The operating system supports at least multi-threading process, file system, and memory management.
[R 16-PI] The operating system includes common networking protocols such as Socket (RFC 147) [2], IP (RFC 791) [3], TCP (RFC 793) [4], and DHCP (RFC2131) [5]
[R 17-PI] The TCP contains Reliable Data Transfer (RFC 908) [6]
[R 18-PI] The operating system will connect to the Internet automatically via DHCP (RFC 2131) [5] once the device is plugged in with the Internet cable
[R 19-PI] All of the networking protocols are satisfied with RFC standards managed by IETF, The Internet Engineering Task Force
[R 20-PI] The operating system is certified as a stable release by the issuer
[R 21-PI] The operating system reached the security, accountability, assurance, and documentation requirements at level C2 stated in DoD85[7]
[R 22-PI] The operating system should contain the basic architecture as shown in the following Figure 3

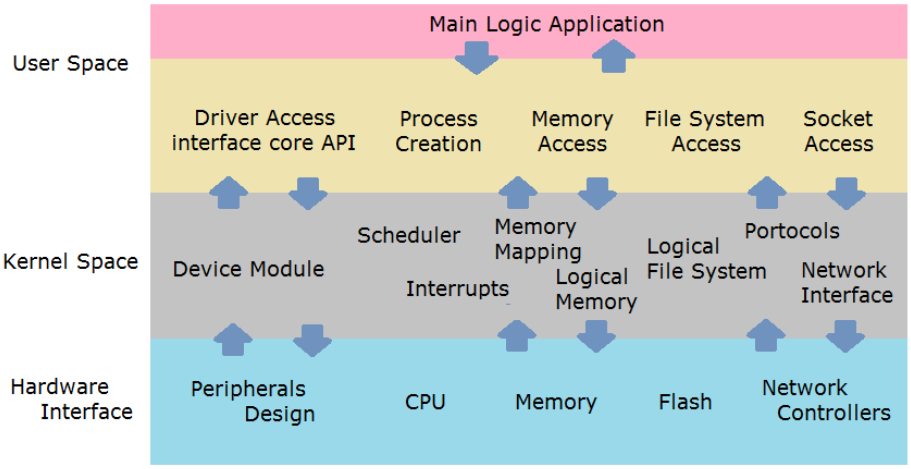

Figure 3: Basic Requirements for Operating System Architecture

3.2.2 Client Application Specification (Main Logic)

[R 23-PRI] The client application can communicates (read, write and control) with hardware components with device driver/module

[R 24-PI] The client application reads hardware data (sensors) from driver in a set interval

[R 25-PI] The client application controls valves according to the scheduled data

[R 26-PII] The client application can push data to remote server using socket after each reading, and it should handle the basic data transfer reliability and security

[R 27-PII] The client application can fetches historical data from server, and it should handle the basic data transfer reliability and security

[R 28-PII] The client application maintains a connection with remote server all the time, and responds to request promptly, and it should handle basic reliability with the connection of server to client

[R 29-PII] The client application includes a scheduling AI, which can schedule the timeline for enabling the valves with the reference data from the user policy, device sensors, Internet forecast (if the Internet connection is available) and historical data (if available), and the scheduling policy should refer to B.C. Irrigation Management Guide prepared by Ministry of Agriculture of B.C. Canada [8]

[R 30-PII] The Irrigation Control Unit will have a unique PIN number and it will be contained in connection from client application software to remote server for identification purpose

[R 31-PIII] The clients adopt secured communication with the SSL, Secure Sockets Layer protocol (RFC 6101) [9] with the server application

3.3 Hardware Requirement

3.3.1 Component Requirement

Certain hardware components are needed to meet software requirements and accomplish expected functionalities. The following content will introduce all required hardware components with their standards based on the minimum acceptable performance of the device.

Component	Requirement
Processor	32 bit or X86 integer range At least 700MHz clock rate which can handle muti-threading and OS responsively The processor must be compatible to linux
Ethernet Controller	Required transfer rate for the device is minor. 10 Mbit transfer rate is sufficient.
Storage	At least 3 GB storage to store OS and application
RAM	At least 512 MiB RAM
Push Button	Minimum 4 push buttons for fundamental operations
LCD Display	LCD area must be large enough (at least 16 * 2 characters) to display all required information
General-purpose Input/output	3.3 V DC output for valve power supply switch 3.3 V DC Input for sensor data wire 5 V DC power supply for sensor circuitry
valve power supply switch	0 V or 24 V AC output controlled by GPIO

Table 1: Required Components

Table 1 summarizes the requirement for these hardware components. To maintain internet connection meanwhile running top level applications requires multithreading, memory management, essential drivers and interrupts functionality. Due to reasons above, an operating system is required for the device. Components such as processor, Ethernet controller, storage and RAM need to be compatible to the selected OS. The

performance and space need to be sufficient so that OS and application can be stored and implemented without a noticeable delay.

Input and output hardware components include push button, LCD display and general-purpose input output port. The device must reserve the controllability of traditional irrigation controllers so that users can still manually control the device. Thus at least four push buttons are required for basic operations. Two of the four buttons are used to adjust the duration of the irrigation. Once the time is set, the irrigation can be activated by press start button and stopped by pressing the stop button. LCD must provide enough space to display remaining time, temperature and soil moisture with correct position on screen. General-purpose input/output are used for input sensor data and the irrigation valve control.

For proof-of-concept and prototype, only one zone will be cover and all hardware components will be included on the developing board. For final products, the device will support multi-zones management. More push buttons and greater LCD will be installed on board for zone selections. Besides, all hardware components will be embedded to printed circuit board with an enclosure which will be included in the following **Physical Requirement** section.

3.3.2 Physical Requirement

Proof-of-concept model and first prototype mainly focus on functionalities including valve control, push button and LCD display which will be all implemented on developing board. For a final product version, an enclosure with PCB inside will be required to prevent damaging the circuitry and protect users from electric shock by exposure circuitry. The following content shows physical requirements for the device and enclosure.

[R 32-PII] Device must have Ethernet cable port, sensor data port and valve power control port

[R 33-PIII] The dimension of the device must not exceed 200 mm×150 mm×60 mm

[R 34-PIII] Weight of the device must not exceed 5 kg

[R 35-PIII] Device must be able to be fixed in the wall by using screws

[R 36-PIII] Push buttons and LCD are embedded at proper position on the enclosure with clear implication of the usage

[R 37-PIII] LCD dimension and push button quantity must meet component requirements

[R 38-PIII] Enclosure of the device must be thermal-insulated-plastic

[R 39-PIII] Enclosure of the device must be anticorrosion material

[R 40-PIII] Enclosure corner and surface must be polished so that no shark edge is presented

[R 41-PIII] The color of the enclosure must be either blue or green to indicate the theme of environment protection

[R 42-PIII] The paint for the enclosure should provide as many following properties as possible based on material cost: heat resist, acid resist, alkali resist and solvent resist [10]

To make the product competitive in the market, the dimension of the device is chosen so that the volume would not be greater than traditional irrigation controller. LCD and push button enable users to manually control the device. Therefore, to display information properly on the device and allow users easily operate the controller become crucial. In terms of the device enclosure, the surface must be polished and sharp corners must be removed to prevent users from injury. Material selection and paint for the enclosure are aiming to increase the durability and safety of the device.

3.3.3 Electrical Requirement

[R 43-PII] The source circuit must be isolated from interferences

[R 44-PII] Power supply for the device is 100~240V at 60 Hz AC

[R 45-PII] Output port for valve power supply must provide 8.4 VA at 24 VAC when inrush and 5.5 VA at 24 VAC when holding

[R 46-PII] Sensor data input must be Boolean input signal: 3.3 V for logic high and 0 V for logic low

[R 47-PII] Output port for sensor power supply must be within range 3.5 V ~ 5.5 V with max current limit 1 A

[R 48-PII] 3.3 V general-purpose output port must be able to control 24 V AC valve

[R 49-PIII] The power plug must conform local standards

[R 50-PIII] Input and output port must companion protection circuit against unexpected high voltage

[R 51-PIII] For the proof-of-concept and prototype, power supply of the valve can be isolated from power supply of the device. For the final product, only one power supply is allowed for the device. Valve power should be transformed from the device power supply

3.3.4 Environment Requirement

[R 52-PIII] The device must work properly under extreme condition (Temperate -30 ºC ~ 60 ºC, Humility 10% ~ 100%, pressure 870 mbar ~ 1085.0 mbar)

[R 53-PIII] The device must work normally without noticeable noise (less than 30 decibel level)

[R 54-PIII] Material of the device should be environment friendly

3.3.5 Safety and Sustainability Requirement

The device contains electronic and electrical components with 24~110 VAC involved, safety will be the crucial element to consider. Safety requirements for a final product model can be mainly divided into two aspects: source circuitry protection and human protection

[R 55-PII] All electronic components must be grounded

[R 56-PII] Wires should be insulated and fixed and outdoor wires should be installed under ground

[R 57-PIII] Power component must possess fuse protection to prevent overcurrent

[R 58-PIII] Electronics must be enclosed and stable

Ideally, the design and its manufacture should follow “cradle-to-cradle” approaches that product material can be either completely recycled (technical) or disposed of in nature environment (biological) when reach the end of product life cycle. Unfortunately, due to the limitation of marketable raw material for electronics and manufacturing methods, wastes can be reduced but not extirpated. Sustainability of final production will be ensured by other considerations such as optimizing circuitry structure, employing recyclable material and design, increasing product durability and life cycle, maximizing substitutable components.

[R 59-PIII] The circuitry design should be optimized to minimize the quantity of electronics components so that PCB area and layers can be reduced

[R 60-PIII] PCB and electronics layout should be compatible to recycle process, including gold, silver and copper

[R 61-PIII] Increase the durability of electronic components as possible

[R 62-PIII] Substitutable components should be maximized so that PCB and electronics can be re-used in manufacturing process

[R 63-PIII] The material of the enclosure must be recyclable

3.3.6 Standard Requirement

[R 64-PII] The device shall conform to CSA Standard C22.2 No. 0: General Requirements - Canadian Electrical Code, Part II

[R 65-PII] The device shall conform to CAN/CSA-C22.2 No.61010-1-04: Safety Requirements for Electrical Equipment

[R 66-PII] The device shall conform to IEEE (Institute of Electrical and Electronics Engineers) 802.11 standards

[R 67-PIII] The device shall conform to CSA 60950-1-07-2nd Ed: POWER SUPPLIES

[R 68-PIII] The device shall conform to CSA Standard C22.2 No 0.4-M: Bonding and Grounding of Electrical Equipment

[R 69-PIII] The device shall conform to ISO standards: ISO 9000 quality management, ISO 50001 energy management and ISO 14000 environment management

4. Environment Monitoring Device

Environment monitoring devices for the system are soil moisture monitoring device and temperature sensor. The reason of the selection is because the common method of determining the irrigation schedule is based on soil moisture of the plant. Temperature is taken into account during irrigation to prevent irrigation under high temperature. Following sections summarize requirements of soil moisture monitoring device and temperature sensor.

4.1 General Requirement

[R 70-PII] Soil moisture device must return water percentage (%) either by mass or volume [11]

[R 71-PII] Measuring range of soil moisture device must be 0~100% and tolerance should be within ±5%

[R 72-PII] Temperature sensor must return environment temperature in unit of Centigrade

[R 73-PII] Measuring range of temperature sensor must -40~50 Celsius with tolerance ±3 Celsius

[R 74-PII] Sensor must be provided with validate functionality to ensure the validity of the data

[R 75-PII] Sensors must be responsive to the enable signal

[R 76-PII] Output for both sensors must be digital and data transferred to controller must be serial transmission to reduce the number of wires

[R 77-PII] The transmission rate of the sensor prefer 10 Mbps or higher

[R 78-PIII] Signals of both sensors must be accurate and stable under long transmission distance (>20m)

[R 79-PIII] Sensors must be low cost and replaceable

[R 80-PIII] The life cycle of the sensor should exceed 10 years

In principle, water condition of the root zone of the plant will largely affect the growth of the plant. Water should penetrate the root zone to encourage deep root growth. However, over irrigation will result in water waste. Thus, the position and the coverage of the soil moisture sensor will be important and relative to the efficiency of the system. Following requirements will describe the position and coverage of the soil moisture sensor.

[R 81-PI] For a proof-of-concept model and prototype, the soil moisture sensor requires at least 10 cm depth coverage. The position of the moisture sensor should be place beside the sample plant

[R 82-PIII] For a final product, the position and coverage depends on the plant species, plant area and topography. The following content illustrates the requirement for special cases

4.2 Position Requirement (Final product)

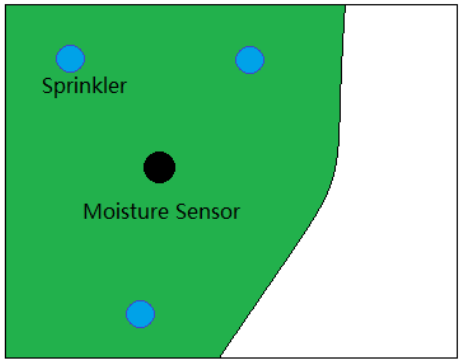

Figure 4: Example of Sensor Position

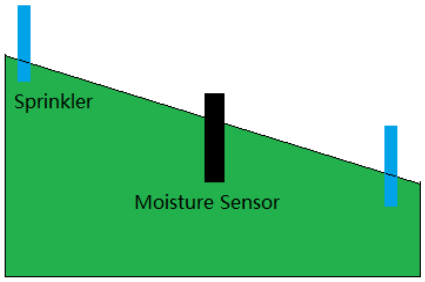

Figure 5: Example of Sensor Position on Slope

To make the moisture data representative, the sensor must be placed at a central position among sprinklers. If the ground is not horizontal, the sensor must be installed at the middle of the slope [12].

4.3 Coverage Requirement (Final product)

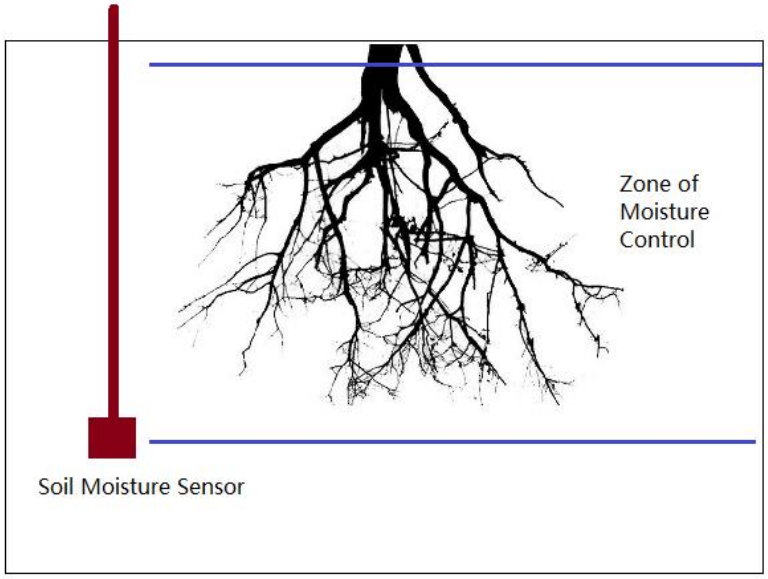

Figure 6: Illustration of Coverage of Moisture Sensor

The underground depth of the moisture sensor should be below the root so the entire root can be covered by the system. According to the type of the plant, depth of the sensor varies which may require installers' additional attention during the first time installation [8].

4.4 Electrical Requirement

[R 83-PII] Power supply of the sensor should be within 3.3V - 6V DC with maximum 2mA current limit
[R 84-PII] The source circuit must be isolated from interferences
[R 85-PII] The output voltage must match to the input port of the controller
[R 86-PII] Circuitry should have LED to indicate the working status of the senor
[R 87-PII] All electronic components must be grounded
[R 88-PIII] Electronic components must be embedded on PCB

4.5 Physical Requirement

[R 89-PII] The probe of the soil moisture sensor should be easy to insert into the ground
[R 90-PII] Wires should be insulated and fixed underground and the insulation must be anti-corrosion material

[R 91-PIII] For a final product, the circuitry of sensors must be placed inside a sealed enclosure which must possess following properties: water proof, heat resist, acid resist, alkali resist and solvent resist

[R 92-PIII] The dimension of a sensor circuitry should not exceed 30mm × 30 mm

4.6 Standard Requirement

[R 93-PI] The device shall conform to IEEE (Institute of Electrical and Electronics Engineers) 802.11 standards

[R 94-PII] The device shall conform to CAN/CSA-C22.2 No.61010-1-04: Safety Requirements for Electrical Equipment

[R 95-PIII] The device shall conform to CSA C22.2 NO 38-05 UPD 2 : EN-Thermoset-Insulated Wires and Cables-Eighth Edition

[R 96-PIII] The device shall conform to CSA C22.2 NO 205-M1983 : EN-Signal Equipment-First Edition: General Instruction No 1

5. Server & Database (Cloud Service)

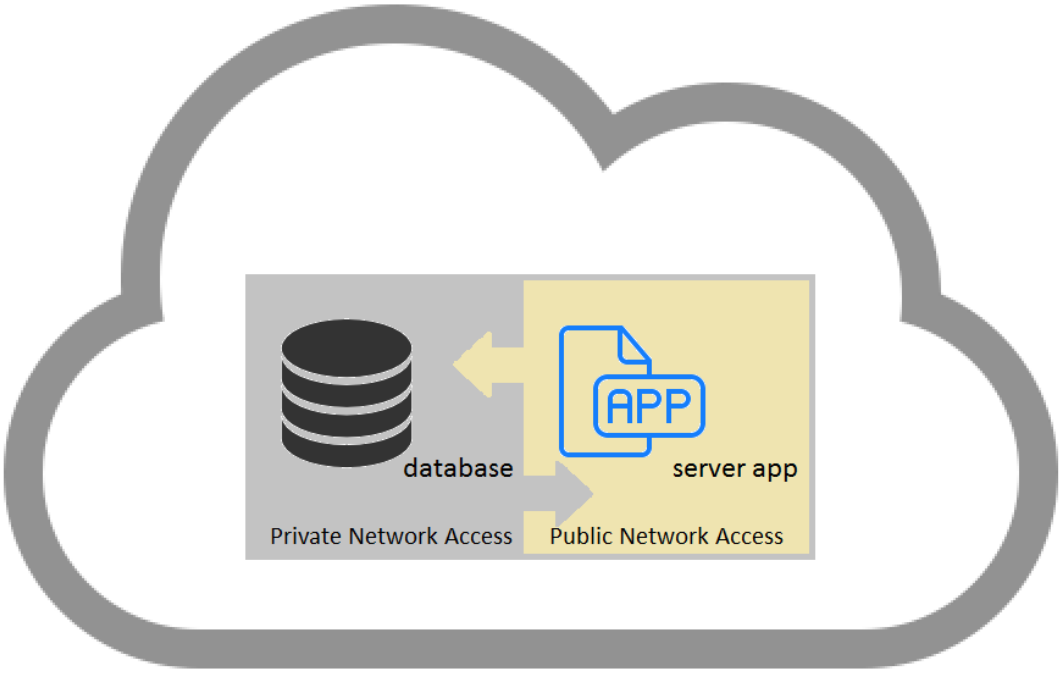

Figure 7: Data Exchange between Database and Server

5.1 Database

[R 97-PI] The database should have data independence and efficient access
[R 98-PI] The database handles data integrity and security
[R 99-PI] The database requires uniform central data administration
[R 100-PI] The database accepts concurrent access
[R 101-PI] The database needs to be able to recover from crashes

5.2 Server Application

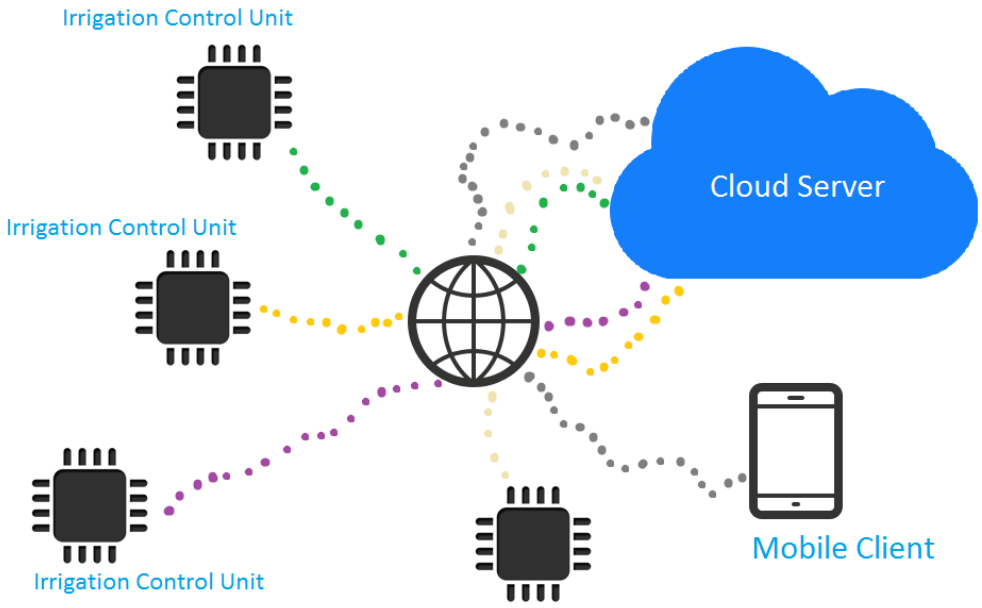

Figure 8: Connection Flows between Clients and Server

[R 102-PI] The server application requires a stable data flow to database server
[R 103-PI] The server application can accept the connections from the client applications and the mobile clients from the Internet, and the basic connection flows are shown in Figure 8
[R 104-PI] The server needs to minimize the data transfer between server and client
[R 105-PI] The server accepts connections from clients concurrently
[R 106-PI] The server use the same TCP (RFC 793) [4] and Reliable Data Transport Protocols (RFC 908) [6] as clients
[R 107-PI] The server application will be stateless; Information is stored in the database
[R 108-PII] The server needs to reduce amount of running connections

[R 109-PII] The server can manage and map the on-hold connections by PIN number from client application in Irrigation Control Unit

[R 110-PII] The server listens to incoming requests from client applications and it can connect to the database and response promptly

[R 111-PII] The server listens to incoming request from Android client and it can either connect to the database response promptly or direct the request to the on-hold connection to client application

[R 112-PII] The server application connects to the remote clients and holds the connection for Android clients

5.3 Safety Requirement

[R 113-PI] The database needs to be protected in private network and not accessible from public network (Design is shown in Figure 7)

[R 114-PI] The server application needs to trust verified clients

[R 115-PIII] The server adopt secured communication with the SSL, Secure Sockets Layer protocol (RFC 6101) [9] with its clients

[R 116-PIII] The server needs to verify the client identity by PIN number and password against its database before passing any device information

The safety for consumers' data is important. The security connection over the cloud should be using TLS Transport Layer Security (RFC 5246) [13], and Secure Sockets Layer (SSL). The server and client should use certificates and hence asymmetric cryptography to authenticate the counterparty. Both client and server maintain a symmetric key, and will use it to encrypt data for communication.

5.4 Networking Requirement

[R 117-PII] The server and the client application in Irrigation Control Unit will be handling connection under the excepted NAT-enabled router environments, as shown in Figure 9

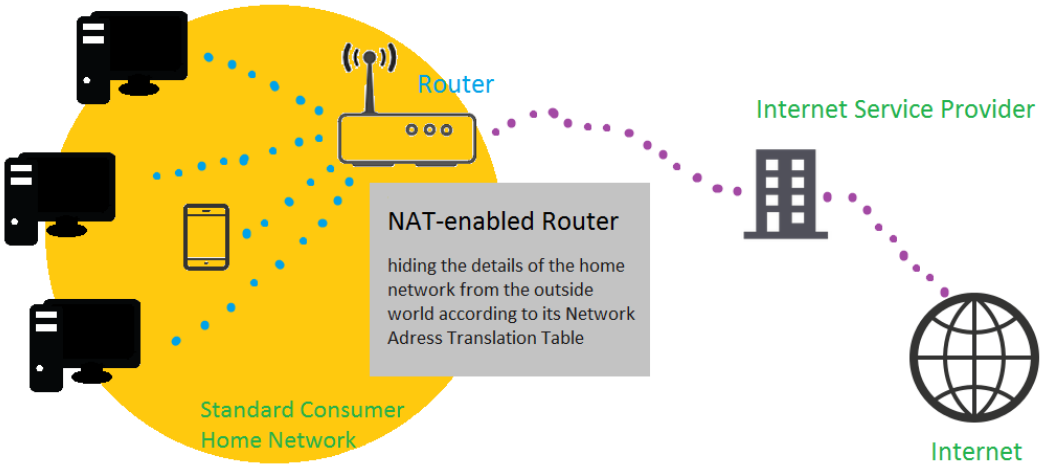

Figure 9: NAT-Enabled Router Networking Environment

The Network Address Translation (RFC 1631) [14] is popularly used in average consumer home network to solve the shortage of IPv4 address at transition period to IPv6 deployment. The NAT-enabled router is hiding the details of the home network according to its Network Address Translation Table, shown in Figure 10 next page.

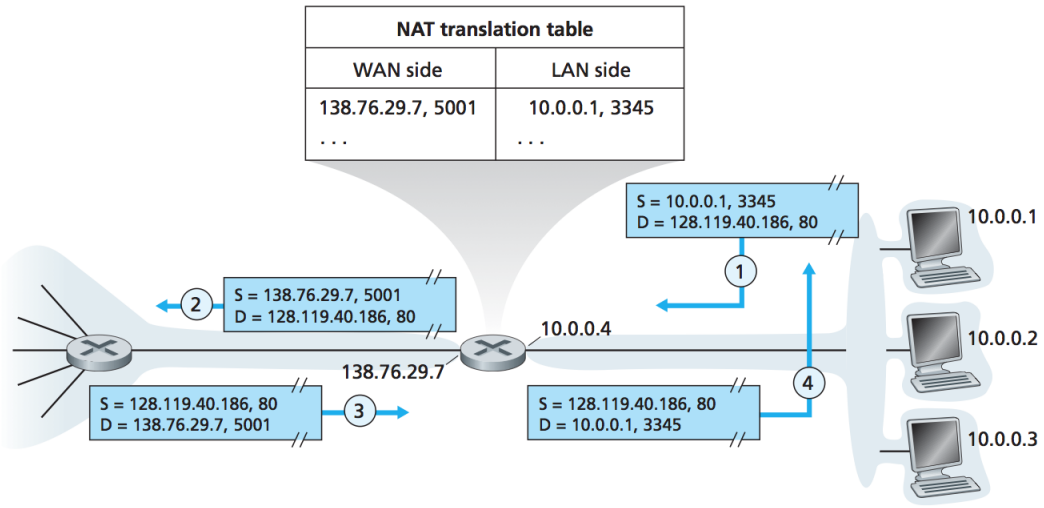

Figure 10: Network Address Translation [15]

The NAT-enabled router will block the ability for the application clients in Irrigation Control Unit unable to accept connection from the remote server by default. The server application cannot create connection to clients, referring to RFC 2663[16] IP Network Address Translator (NAT) Terminology and Considerations.

The requirement is to let the server able to communicate with client, once the Irrigation Control Unit is connected to the internet at home, and without user have to modify the router settings

6. Mobile Phone App

The smartphone app plays an important role in user-system interaction, the app functions are included in the Figure 11 next page.

Due to time and budget concern, for the proof of concept and prototype the smartphone app will be developed under Android operating system which requires a touch screen Android phone with minimum screen resolution of 640dp x 480dp [17]. Too small resolutions will not be enough to support the User Interface display. Because of different Android system versions, the app will not be able to function if the system versions are far outdated. Therefore, the app will run on the API level 8 for higher.

The smartphone app will not responsible for generating the schedule unless the users made any modifications on the schedule. In most cases, the app plays the role of user interface and displaying data received from the server. From the diagram, the Account Management feature is a key to all other features and is necessary to have it for separating users and protecting privacies.

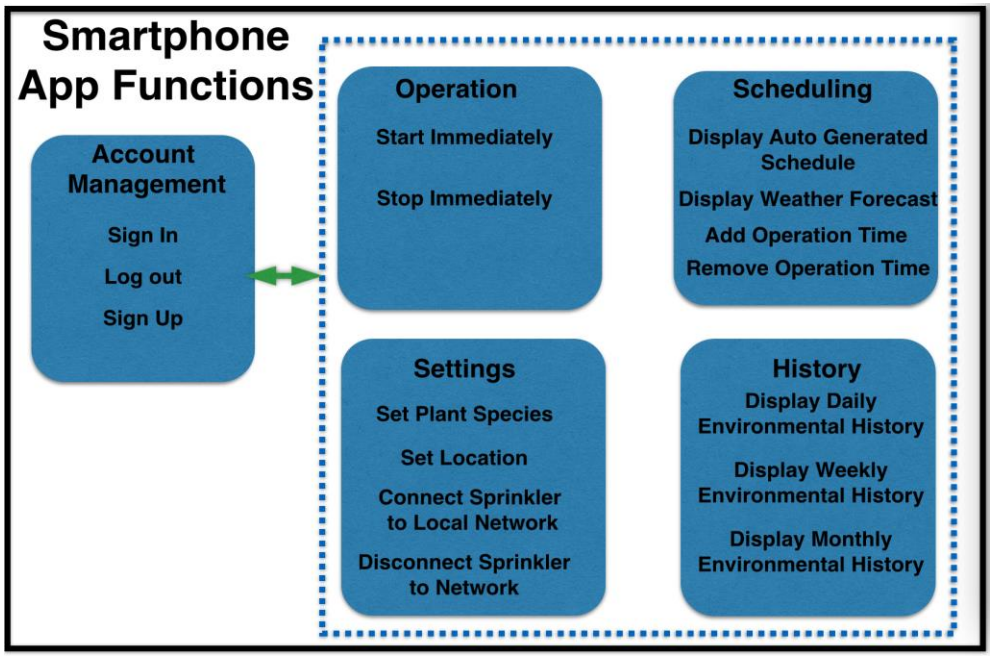

Figure 11: Smartphone App Function

6.1 General Requirements

[R 118-PI] Based on Metro Vancouver Water Shortage Response Plan (WSRP), the app must restrict residential address users setting sprinkling schedules within 4AM to 9AM and non-residential users scheduling within 1AM to 6AM [18]

[R 119-PII] The app must clearly indicate the date and the current time on the user

[R 120-PII] The user interface of the app shall inform user the percentage and time of the sprinkling progress when a sprinkler is operating.

[R 121-PIII] The app shall auto adjust sprinkling schedule under the local sprinkling regulations.

[R 122-PIII] The data loading time for the app shall be less than 5 seconds any process that takes longer than 5 seconds will give a failure message.

[R 123-PIII] The app shall remind users whenever their mobile device loses the connection to the Internet.

[R 124-PIII] The app shall allow users to select plant species to help setting a suitable sprinkling schedule based on plant species.

6.2 Safety Requirements

[R 125-PII] The app must allow user to sign in and log out with a valid email address as user name and at least 6 digit case sensitive password for privacy protection concern.

6.3 Usability Requirements

[R 126-PII] The app must allow users to control the sprinkler by turning it on or off immediately.

[R 127-PII] The app shall has the feature of adding and removing the sprinkler schedule.

[R 128-PII] The app shall allow users to manually adjust the duration of sprinkling time.

[R 129-PII] The app shall provide user the information of the current weather and the weather forecast within a day and the next day.

[R 130-PIII] The app shall allow users to check the sprinkler operation history and environmental statistics in daily, weekly, monthly and annually bases.

[R 131-PIII] The app shall has the feature of controlling each sprinkler separately among all the sprinklers that are connected.

7. System Test Plan

The general approach to system testing consists of the testing of each individual components and the collaboration between each component after they have been assembled. Once we have complete the development of the proof of concept, a simulate trial will be performed to ensure the requirements of the proof of concept has been met. The test plan consist of two steps. First, each individual components will tested so fundamental error will be easily spotted and corrected. Then an integrated test will be performed to exam how components cooperate with one another. The following sections contains the detailed testing procedure and expectation for each step of the test plan.

7.1 Individual Component Test

7.1.1 Hardware

The test plan of hardware contains the examinations of the temperature sensor, the soil moisture sensor and the control unit. The control unit is a combination of several individual component including a processor, a storage, a RAM, power supply, four push bottoms and a LCD display. The operations system of the control unit should meet requirements from section 3 which include but not limit to the memory size, and the processing speed. This would require the proper functionality of the processor, storage and RAM. Therefore, the control unit will be tested after its components has been approved. While the test plan for hardware focus on the control unit, there are also several manor tests for the sensors to make sure they meet the requirements of the proof of concept.

The following tests will be performed to ensure requirements from section 3 and 4 has been met.

Irrigation Control Unit

- The OS should be able to run with the space provided by the storage and RAM
- The operation interface is correctly displayed by LCD display
- Command sent from push bottoms are correctly operated by operation system and responded by the LCD display without noticeable delay
- Power is safely supplied from power source and send to requesting ends.
- Capable of turning on and off the valve according to command sent from control unit within tolerable delay

Environment Monitoring Device

- Remain functional under low temperature down to -30℃ and high temperature up to 60℃
- Date gathered should be within tolerance and stably sent back without noticeable delay

In general, all hardware should meet the requirements from section 3.3.4 (environment requirement) In addition, outdoor hardware should be resistant to repaid temperature increase due to sunshine or decrease due to snowing.

7.1.2 Software

Mobile application

The mobile application should meet the requirements from section 6, and will be first tested as individual component without considering the interaction with other components. The following will be the examining target for our test plan.

- Capable of running on a targeted android device without frequent crushing
- Correct visual appearance of user interface
- Should be able to work as presented by the UI without noticeable bug
- Correctly display the data received from server and the desired command is sent out to control units through the server

Operation System

The operation system is installed on the control unit and allows the irrigation system to behave according to its surroundings. It is one of the most important component for the irrigation system. Therefore its function must fulfill the requirements from section 3. Similar to mobile application, its examination will be performed as an individual component without considering any interaction.

- Data gathered should be processed as expected
- Capable of stably transfer data without any loss
- Should be able to continuously work without crushing

Server & Database

The server act as a bridge for the control unit and mobile device. All commutation between the control unit and the mobile device will go through the server and the server will record the necessary activity history.

- The server should be capable of hand rapid data exchange.
- The server should be crushproof. The effect of crush due to any cause should be minimized.
- All data stored should be extracted without any loss.

7.2 Integrated Test

The integrated product will be evaluated after all individual components has been prove to work properly and are assembled. One of the highest priority is the accurate execution of commands sent from the user and most tests will be focused on this area. The following tests will be preferment and adjustments will be make accordingly. All "tolerable delay" involving the server varies according to different situation. The actual command, the single strength and its blockage will be several affecting factors.

- The commands sent from mobile devices should be executed by the control unit within tolerable delay.
- Information gathered by sensors should be undated by mobile app within tolerable delay.
- All information should be exchanged within tolerable delay.
- Expected commands from mobile app are received by control unit, and are correctly executed by the end units.
- Each set of control units and mobile device are bonded and the information exchange should only take place between the corresponding partners.

8. Conclusion

This functional specification clearly defines the capabilities and requirements of the C-Sprinkler by the priority of importance. Our product has two developing phases and we are currently at first phase which is working on the first prototype. We are confident that our product will meet all the expected requirements listed above and we are aiming to finish our first prototype in the late November 2014.

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