QATra Irrigation System

Final Report

Texas A&M University at Qatar
ECEN 403: Electrical Design Lab I

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“An aggie doesn’t lie, cheat or steal, or tolerate those who do.”

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Abstract

The aim of this project is to reduce the overuse of water in agricultural lands and improve the efficiency of irrigation systems in Qatar. Qatar National Vision 2030 aims to achieve sustainable development to ensure a better life for future generations. Optimum use of our natural resources is a target that we have to look forward to in this century as a result of global warming. One of those natural resources is water, which is a precious commodity in Qatar, and thus it has to be used wisely. Therefore, we propose an advanced irrigation system, QATra.

QATra is an advanced irrigation system that has the ability to reduce water consumption by checking the soil moisture and controlling the amount of water dispensed. A mobile application, where the user can view the daily water content of the soil and gets notified when the plants are watered, is used in our system. The user is informed in case of a potential fault in the system and is able to control the irrigation system using the application. The project addresses environmental issues, cuts labor costs, encourages smart innovations and boosts cultivation.

Exploring research papers that were done regarding smart irrigation systems combined with feedback obtained from our potential consumers and experts in the field gave us insights and technological perspectives on our proposed project.The significance of examining and studying different groups of audience is that each group had different and important information to help in prospering the design.

There are various products in the market that have similar design to our proposed solution. Attaining knowledge and getting familiar with the current products available, helps us to be aware if our project is within the trends of the market, whether it provides services not available by other products or if its design requires any improvements. The products were compared to our project in terms of technical and non-technical criteria. The non-technical criteria included: public health, safety, risks and welfare, as well as global, cultural, social, political, ethical, environmental, or economic factors.

From these extensive studies, we were able to identify the design of our system as a whole and with a detailed decomposition, as well as determining the different mathematical, scientific and engineering aspects in our project. The standards used and the constraints and risk of our design were identified. Different courses had a huge link to our project. Those courses are: ECEN 420, ECEN 210, ECEN 489 and ECEN 449.

This report includes five different chapters. The first chapter discusses the literature review and customer needs analysis. The second chapter includes the benchmarking and the criteria that the comparison was based on. The third chapter includes our functional modelling as well as its detailed decomposition. The fourth chapter includes: detailed system design and its components; the technical standards, constraints and risks; and the link between our project and the ECEN courses we took. The fifth chapter includes the progress made, timeline, next semester plans and the conclusion.

Chapter I: Literature Review and Market Needs Analysis

1.1 Literature Review

Qatar is a peninsula Arab country that has a total area of 11,586 km_2 which is located on the west line of the Arab Gulf [1]. Qatar is classified as a desert country and with its extremely hot weather it reaches very high temperatures in summer and warm winters. As a result, rain is very rare in Qatar with an annual average of 80 mm of rain water [1]. Also, Qatar has poor natural water resources since it has no rivers or lakes. However, there is one natural water resource which is groundwater, but the groundwater does not cover the water needs of the country which is an estimate of 750 million m_3 of water per year [1]. So, Qatar started to desalinate the seawater which is mainly for domestic usage and treat used water which is mainly used for agriculture [1].

Although the water demands for the country are being supplied by groundwater, seawater desalination and treating used water, Qatar is facing water scarcity. First, the rate of extracting groundwater is much higher than the refilling rate of accumulated rainfall drained in groundwater [2]. Second, seawater desalination process is costly and uses natural gas as fuel which is a non-renewable energy source that increases the emission of CO_2 in Qatar and accelerates global warming [2]. Finally, the consumption of water per person in Qatar is 500 liter per day per which is one of the highest consumption rates in the world [2]. Water scarcity is a heavy contributing factor to the limitation of agriculture and food production. Simultaneously, global warming as a result of high CO_2 emissions is causing an environmental threat to the whole world. Global warming effects can be minimized through cultivating agricultural lands. Therefore, there is an obvious link between water scarcity, agriculture, and global warming [3].

As a result, we came up with the idea of an advanced irrigation system that reduces water consumption in agriculture. In order to find the current solutions, potential customers opinions, and market needs of advanced irrigation systems, literature review, surveys, and interviews were conducted.

Ogidan, Onile, Adegboro [4] proposed the idea of smart irrigation system in their paper. The system has two major components. First, the moisture sensor is used to take readings of the moisture level in the soil. Next, the readings are sent to the microcontroller that analyzes the readings and takes action. If the soil was underwatered the microcontroller sends a signal to the pump to start watering the plant until it reaches the normal moisture level.

Abba, Namkusong, Lee, and Crespo [5] also had a very similar idea in their research. They proposed the idea of smart irrigation system that consists of a controller which is connected to a moisture sensor and a water pump. The controller is taking the measurement from the moisture sensor and deciding whether the plants should be watered or not. The main difference is that they were able to send the data to an analytical and visualization website that views the readings.
Shruthi, Kumari, Rani, and Preyadharan [6] used the Arduino software to design the project. The automated sprinkler system will be activated on the basis of the results. The output of the humidity sensors will be displayed on a screen. It minimizes human interference and water runoff over the saturated soil.

Tarange, Mevekari, and Shinde [7] have built an automated wireless irrigation system using WSN and embedded Linux board for collecting information from sensor nodes continuously, store it in a database and then provides a web interface to the user. It helps to analyze the soil parameters and reduce water consumption. Web interface and automation helps the user to monitor the system and minimize human intervention.

All of the researchers had done significant work regarding smart irrigation systems. However, there are some missing pieces of the puzzle that needs to be put into place in order to get more efficient smart irrigation system. QATra irrigation system aims to include these missing pieces by combining automated irrigation system with control through a mobile application with a fault detection feature.

1.2 Customer Needs Analysis

The surveys and interviews that were conducted was to identify the needs of the customers (i.e. what would the future consumers like to see in such product), whether people accept this idea and are willing to have such products at their homes/farms/agricultural land and what constraints we might face as undergraduate students working in a field that is not ours (e.g. agricultural knowledge, creating the piping system for the irrigation). The survey will allow respondents to express their ideas and views without questioning. Also, the survey charts were used to draw a conclusion from the answers received from the majority. On the other hand, the interviews with engineers and agricultural specialists will give us a better understanding of the technical and agricultural aspects used in our proposed design.

1.2.1 Survey 1: Specialist Interviews

While we were conducting our survey, we had an interview with Engineer Ahmad Shaker, an automation engineer at Public Parks Department at the Ministry of Municipality and Environment. The team asked Engineer Shaker about irrigation systems currently used. He replied that the irrigation system used now is distributed water sprinklers among different cities and places and are controlled through a centralized software installed in one of the computers at Public Parks Department. The irrigation system waters the plant at an earlier scheduled time. Also, the user can shut down the whole irrigation system at a place such as Sheraton Park. However, one single sprinkler cannot be turned off independently.

We asked about fault detection in the system, he responded that they can know if there is water leakage through comparing the normal flow rate of the water and the current flow rate of the water through a water sprinkler. But the user is not informed about it.

Then we explained our proposed irrigation system to Eng. Shaker. His feedback was positive about our project. Eng. Shaker confirmed that the usage of moisture sensor can decrease the amount of water needed to water the plants. We asked if the system needed other features, Mr. Shaker proposed that other sensors such as salinity and temperature sensors can be added to improve the system.

A second interview with two project engineers from Kahramaa (Qatar General Electricity and Water Corporation): Engineer Ayman Mashali and Engineer Mohamed Ben Aicha was conducted. In the interview, we discussed ways in order to effectively improve our design. Engineer Ayman highlighted the importance of taking into account the characteristics of each plant (e.g. their root types), the water content needed by each plant and the soil type used here in Qatar in order to elaborate the moisture sensor.

When the group asked about the constraints we might face, the Engineers mentioned two significant ones. First, Engineer Ayman mentioned that social acceptance might be an issue, since people now are reluctant to try new products and that’s why we should try to promote and explain our project to people. Second, Engineer Mohamed mentioned that our system might face many technical problems, such as poor water flow rate, and therefore the system must be tested with different scenarios. Both of them emphasized that maintenance is an important aspect of our project, it should be considered when estimating the price of the product. Finally, both of them showed great interest in our project. They both agreed that this project will contribute in reducing the amount of water being dispensed, especially that the agricultural sector consumes the most amount of water in Qatar.

A third interview was conducted with Mr. Osman Ahmed Abdalla, who is an agricultural affairs consultant and an agricultural specialist form the Ministry of Municipality and Environment. While conducting research for our proposed project, we came across many obstacles that should be taken into consideration in order to produce a more practical and well-functioning outcome. Many of these obstacles and constraints were related to agriculture. One of the most important questions that we asked Osman Abdalla to clarify the best place in the soil to place the sensors in which he said that its vital for the sensors to be placed in the root zone. He also mentioned that the root zone differs for different plant species, so it affects the level of soil depth for sensor placement.

Mr. Abdalla brought up that some other constraints we might face is that each type of plant has different water level requirements, each phase of growth requires different water levels and the different seasons has an effect on water levels. Unfortunately, he didn't have any data regarding water threshold level for different types of crops but he recommended to get these data from the Food and Agricultural Organization (FAO). Moreover, we asked if the type of soil used can affect the readings of soil moisture level. He explained that different types of soil such as sandy soil and silt soil has different water holding capacity. He added that in Qatar the most common type of soil used is sandy soil and the most common type of crops are vegetable crops and animal food. He advised us to use a mixture of sandy and clay soil for our prototype since this mixture is better for cultivation.

Furthermore, we asked how many times during the day should the sensor take soil moisture measurements and for how long should the irrigation system be on. He mentioned that taking the soil moisture level twice a day is enough preferably one in the early morning (best time for irrigation) and one in the afternoon or at night, he added that the irrigation system on time should be organized depending on the amount of water each crop needs to intake in one day where these data can be found from online research or the FAO. Lastly we asked some general questions regarding our project such as if there is a smart irrigation system currently in use, where he replied that this idea has not been implemented and that having a fault detection notification is better for monitoring rather than having to physically check the system every time.

1.2.2 Survey 2: Online Questionnaire

The online questionnaire was targeting the general public. Total number of respondents was 202. The questions that were asked in the questionnaire were general and straight forward about our project. To begin with, we asked the respondents about their interest in a smart irrigation system. We obtained 202 responses were the majority (73.63%) were interested in a smart irrigation system as shown in **Figure 1.1** and **Figure 1.2**. 17.41% of respondents answered that they might be interested in such a product. 61.11% of the minority respondents who were not interested in such systems (8.96% of the total respondents) didn't own a farm or garden. This analysis shows that there is demand and overall acceptance of such innovative irrigation system.

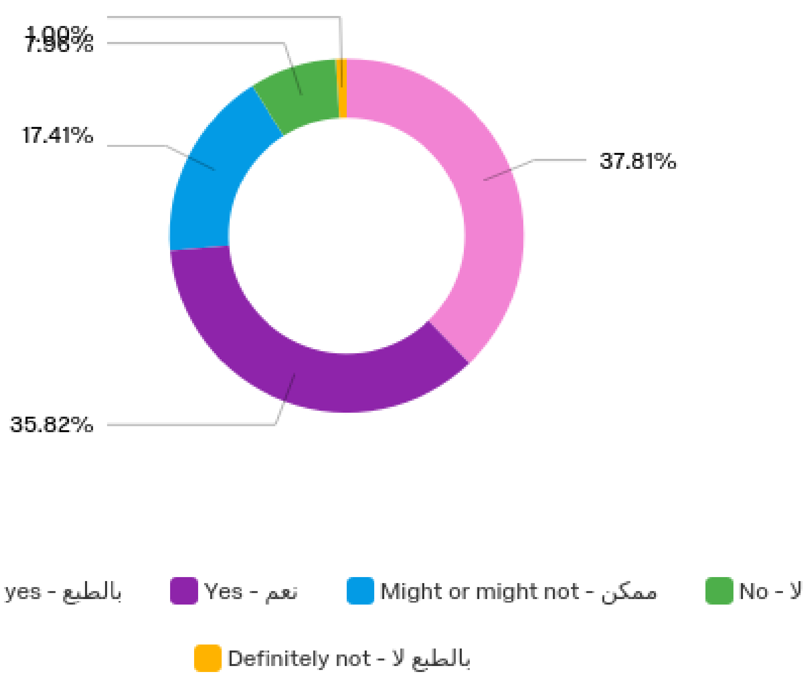

Figure 1.1: Respondents' answer to whether they are interested in a smart irrigation system shown as a pie chart.

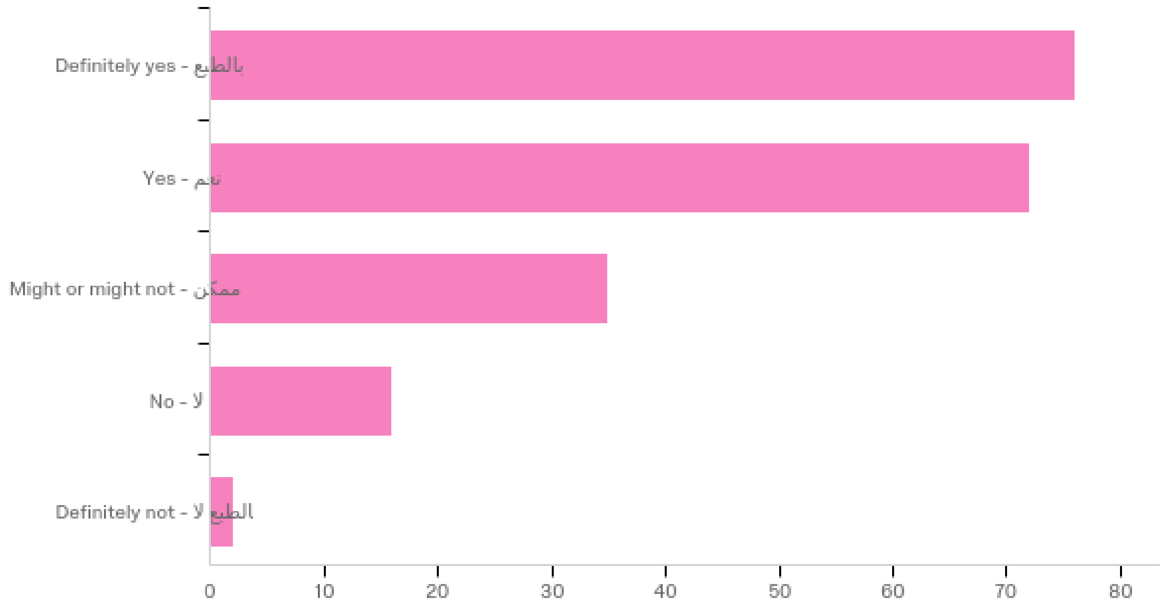

Figure 1.2: Respondents' answer to whether they are interested in a smart irrigation system shown as a bar chart.

Next we asked the respondents if they own farm or garden. 70.85% of respondents owned a farm/garden. Out of these, 47.86% were not familiar with such a project. This information proves that our idea is innovative and might encourage the usage of more eco-friendly smart systems.

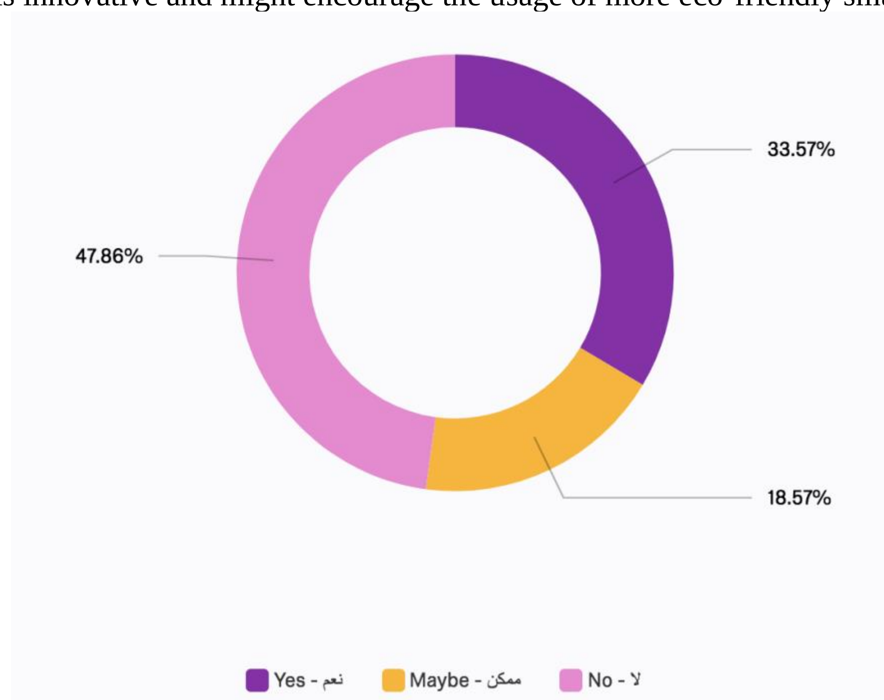

Figure 1.3: Respondents',who own a farm/garden, answers to if they are familiar with such system.

Furthermore, people were asked about the specifics of our proposed design which was regarding the application feature. Most of them, 65.67%, think that the application feature makes it more convenient to monitor and control the system as shown in **Figure 1.4**. This shows that people are willing to improve on the traditional methods of irrigation. On the other hand, 32.34% said “Maybe” and the remaining (1.99%) said that the application feature will not make the irrigation process convenient.

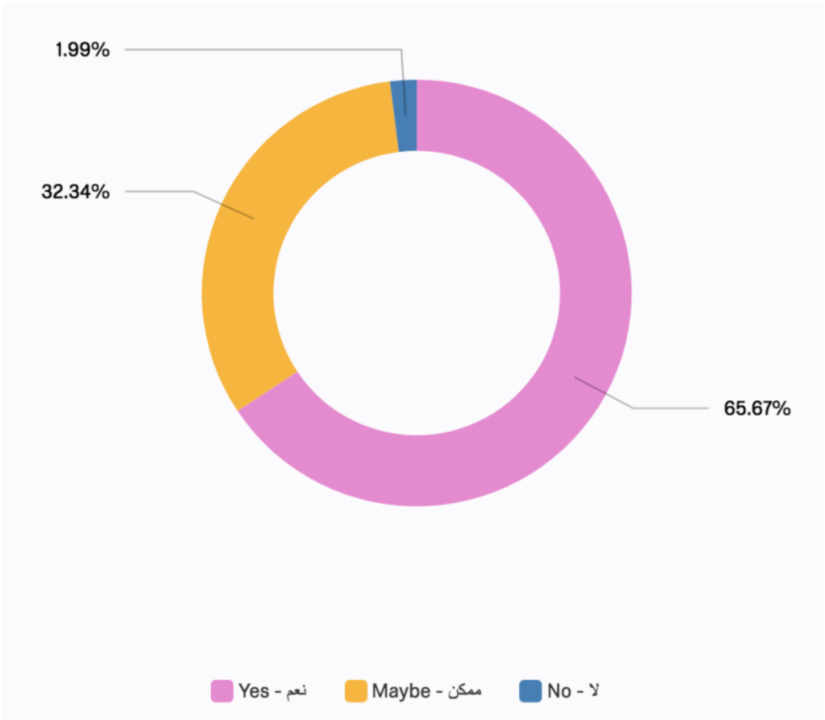

Figure 1.4: Respondents’ answers to whether the application feature makes it more convenient for them to control and monitor the system.

Then we asked if our project helps in reducing water wastage and advocates environmental issues such as global warming. 78.61% of the respondents agreed that our project will reduce water consumption and raise awareness about environmental issues, as shown in **Figure 1.5**. 19.40% of them said that out project might help. However, the remaining respondents (1.99%) said that it will not help in reducing water consumption nor advocating environmental issues. This information supports our main idea that our product will reduce water consumption and raise awareness regarding environmental issues while advocating cultivation.

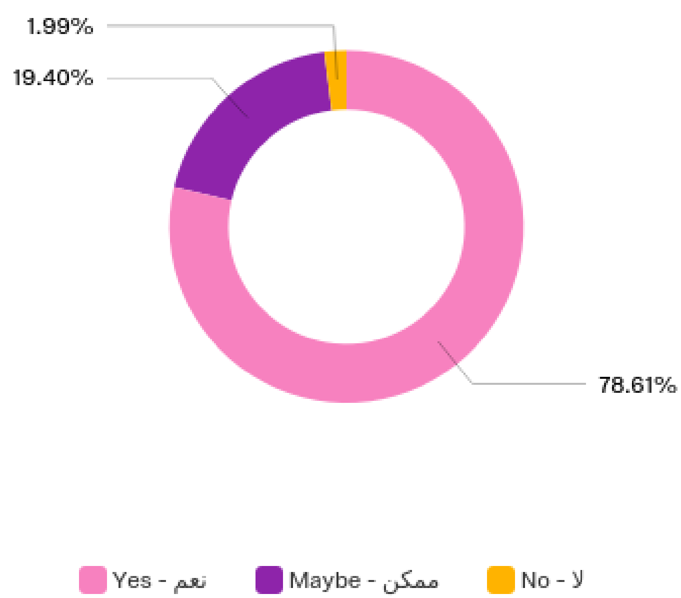

Figure 1.5: Respondents' answers to does our project helps in reducing water wastage and advocates environmental issues such as global warming

We asked the respondents if they have any additional suggestions or features that they would like to improve on our project. We received many opinions. In this section, we will highlight the most important suggestions. A suggestion that grabbed our attention was that this system will be implemented in gardens/farms outside buildings, and usually the Wi-Fi connection outside will have a low signal. Also, one respondent suggested to incorporate the effects of pest control and environmental factors on our system. Moreover, two respondents mentioned that they would like to see certain data in the app. The first wanted to view the daily, monthly and annual water consumption and the second wanted to know how much water was saved from this system in comparison to regular systems. All those suggestions shall be taken into consideration and some can be implemented in our system.

The questionnaire we conducted showed that the majority of respondents were not familiar with a smart irrigation system. Also, none of the experts we interviewed operated a smart irrigation system in their respective companies. This is very important since we can use the smart technology, we are designing in something necessary and something we depend on (for agriculture and food production) like irrigation systems. Also, we aim to use this technology for a greater good: to help save our environment by consuming less water for sustainability.

We anticipate that our advanced irrigation system can be implemented in large areas with different types of crops. Each water sprinkler can be controlled individually depending on the moisture level of the surrounding soil. Each water sprinkler and sensor will be connected to the controller which will manage the watering process depending on the moisture soil level of each sensor. The measurement of each moisture sensor will be sent to a mobile application, where the user can view the reading of the sensors during a specific interval. In addition, the user will be notified whether one of the sprinklers is damaged/leaking or if the sensors are not working properly.

1.3 Types of Resources Used

It was important to disclose many different types of information regarding smart irrigation system in order to obtain different perspectives, opinions, areas and backgrounds on this matter. We thoroughly explored different types of research papers from reliable sources that is closely related to our subject matter. However, only a few research papers stood out and grabbed our attention due to its similarity approach and objectives. These papers were extensively analyzed and discussed. From these papers, we sought out what were the missing pieces of the puzzle which was considered in our own proposed design.

Moreover, it was important to gain some insight directly from potential customers and experts who work in this field (engineers and agriculture specialists). The methodology that we considered was to gather information from wide ranges of audience with different point of views regarding smart irrigation systems. Therefore, we conducted an anonymous online survey for the general public in English and Arabic to examine their reactions and acceptance towards our proposed product and to observe if there is a demand for such product. On the other hand, we wanted to gain knowledge and feedback of specific technical information from experienced engineers of different fields and agricultural specialists. Interviews helped us to gather information from an experts' experience in the field which will be a valuable input to our project.

The significance of examining and studying different groups of audience is that each group had different and important information to share. For example, research papers gave us a better understanding on the technology advancement on irrigation system and its benefits. Similarly, the general public gave us insights, comments and suggestions about our proposed design in general such as the application features and whether there was demand for such product. On the other hand, discussing with engineers and agriculture specialists gave us a deeper understanding of technical and agricultural perspectives and awareness of the possible constraints and risks that we might face while working on our project.

Chapter II: Benchmarking

2.1 Existing Solutions:

There are different products and papers written about irrigation systems. The functionality of some products are discussed here. This section is divided into three parts. The first part will include products which are currently existing in the market as these will be compared to QATra based on the benchmarking criteria that will be discussed below. The second part of this section will include literature reviews of irrigation systems while the third part will include the conventional methods of irrigation.

2.1.1 Existing products:

Rachio 3:

The Rachio 3 smart sprinkler system [8] is the most popular product among smart irrigation system devices. The Rachio 3 is a device that replaces the controller of a current automated sprinkler system and can fit up to 16 zones of sprinklers (prices differ depending on the number of zones). The sprinkler cannot be controlled through the device itself instead full control happens through the mobile application of Rachio 3. The mobile application is available for both iOS and Android where Rachio 3 can be connected using the user Wi-Fi network (supports both 2.4GHz and 5GHz). The Rachio 3 mobile application has useful features such as weather intelligence which connects to many different sources of satellite, radar and weather station data, when the user enters the location, in order to check for any rain or wind that might affect the irrigation. If it was found that on a certain day it might rain, then it will stop the irrigation system. Moreover, it allows the user to input a detailed plan for the system such as the water scheduling days, scheduling times and the duration of watering the plants. The application allows the user to alter the system plan according to the season. The app notifies users when the system is watering the plants.
Although Rachio 3 is a great product, it has some constraints. First, it has a limited number of zones which can be covered. Also, fault detection feature is not available in Rachio 3. However, a flow meter can be added with additional cost to detect water leakage. Sensors are not supported in this product. Thus, plants can be affected with underwatering or overwatering.

Orbit B-hyve:

Orbit B-hyve Smart Wi-Fi Indoor Timer [9] is a smart watering system. This product cover from 4 up to zones and price varies with the increase in the number of zones. Some of Orbit B-hyve features include weather sensing technology and smart scheduling which identifies watering options based on gathered information on the slope of a crop, type of soil, amount of sunlight and live weather updates. The app works with iOS, Android or web browser and can be connected using Wi-Fi network (supports 2.4Ghz). The mobile application can create a program for water scheduling, or the user can do it manually. The user also has a built-in manual watering override which allows to start and stop watering without using the app.
Orbit B-hyve is a very powerful product. However, there are some barriers that can be overcome. For instance, users may not take full advantage of the smart scheduling feature as they might not have enough knowledge and information on the crop. This product does not support any type of sensors so the plant may compromise for overwatering or underwatering.

Hydrawise Hunter HC:

Hydrawise Hunter HC is a smart sprinkler controller [10] which gives detailed reports about the amount of water used, rainfall amount and also gives alerts about broken pipes, spray heads, faulty wiring and valves. Its available from 6 to 12 zones and the price varies depending on the number of zones. It also stores past watering history so that the user can view the report. It can be used only indoors. It can connect to a maximum of two sensors which include the Hunter rain sensor. Its available for both iOS and Android devices and connects using Wi-Fi network of bandwidth 2.4GHz and is not compatible with 5GHz.

Despite the fact the Hydrawise Hunter HC is a successful product, it can be further improved and developed. Hydrawise Hunter HC can cover only a limited number of zones. Also, fault detection is supported in this product unless flow meter was installed with additional cost to detect leaking. Rain sensor can be implemented with additional costs.

BlueSpray:

BlueSpray [11] is a smart sprinkler which controls the watering schedule by using the website rather than a mobile application. It uses weather forecasting to schedule the watering time. The number of zones for this product can reach up to 24 zones and the price increases with the increase in the number of zones. It uses weather forecasting, but the controller does not stop the sprinkler if it rains and the rain sensor is required to stop watering the plants during rainy days. History reports of watering schedules can be viewed by using the website. The types of sensors that can be added to Bluespray are rain and flow sensors. However, these sensors do not come with the controller and the user have to buy them separately. It is compatible with both 2.4GHz and 5GHz Wi-Fi networks.
BlueSpray is a very good product. However, it can cover a limited number of zones. Also, the user interface is a web browser, which makes it harder for the user to control and monitor the system. Fault detection feature is not available in this product. However, leakage may be detected if a flow meter was added with additional cost. Moreover, rain sensor might be added to the controller with extra cost.

FCC electrical specification standards:
All of the four products comply with the FCC rules. Federal Communications Commission (FCC) [12] are in charge of different responsibilities. One of them is setting a number of rules and regulations in the United States to ensure that devices are at a reasonable price and that devices does not cause harm.

2.1.2 The conventional methods of irrigation systems:

The conventional methods of irrigation systems use hoses are pipes that pressurized water flows through it and is used in watering plants. Water is dispensed from the pipes or houses using sprinklers or drip irrigation. During our interview, we asked them Mr. Osman Ahmed Abdalla, an agricultural specialist about current fault detection techniques. He said to detect any faults in the system a person should physically monitor and check the system. The system is controlled using a timer to activate sprinklers for a set amount of time in order to water the plants. This method does not take into account the threshold values of plants and overwater may occur.

2.2 Performance Criteria

After looking at the different solutions whether they were research or products, we found that there were still some missing pieces of the puzzle that need to be put into place in order to get a more efficient smart irrigation system. QATra irrigation system aims to include these missing pieces by combining automated irrigation system with control through a mobile application with a fault detection feature.

Our design meets specific needs with consideration of the following factors:

- Environmental:
  Our project has a direct link to environmental factors where it helps in preserving water resources and contributes to increasing agriculture.

- Public Health:
  Our project has an indirect link to public health benefits, where increasing the level of agriculture can increase levels of oxygen and decrease the level of carbon dioxide in the air. This leads to a better quality of living due to cleaner air. Increasing agricultural productivity can also mean better quality of food.

- Welfare:
  Our project has an indirect link to welfare. As public health improves, welfare will increase. Moreover, the project promotes smart innovations, which can indirectly help in increasing welfare.

- Economic:
  Our project has a direct link to economic factors. Less water will be used for agriculture which will improve the economic benefits. Also, more agriculture will cause a better economy and less dependency on imports. Statistics from the World Bank showed that Agriculture accounted for one-third of global gross-domestic product (GDP) in 2014 [13].

- Safety and Risks:
  Our project has a direct link to safety measures, where they have been taken into account in our design, the interaction of water and electricity can cause a huge hazard and therefore all electrical appliances will be in waterproof, transparent boxes. Moreover, there might be potential risks that might face our project and we have to keep them in mind. Those risks include the stopping of the main microcontroller and losing the Wi-Fi connection. Both the risks and safety constraints are elaborated in Section 4.2.

- Social and Global:
  Our project has an indirect link to social and global factors, since it aims to raise awareness about global warming and water scarcity in the world.

- Cultural:
  Our project has an indirect link to cultural factors, since we aim to create a culture of preserving natural resources.

- Political:
  Our project has an indirect link to political factors, since one of our aims is to preserve natural resources, which is a big part of many political movements worldwide.

- Ethical
  Our project has direct link to ethical factors, since as we want to be ethical engineers, we have to "disclose any factors that might endanger the public or the environment." (IEEE code #1)

Therefore, in this benchmarking assignment, we will be comparing products based on technical criteria and the certain considerations that we mentioned.
Technical criteria:

- fault detection
- zones
- user interface
- weather intelligence
- sensors availability

The considerations that will be used in the comparison are:

- cost
- water preserving
- safety
- promoting smart innovations
- Raising awareness (global issues such as: water scarcity and global warming)

2.3 Benchmarking Table

The following table shows different products compared to QATra irrigation system under the criteria that were discussed in the benchmarking criteria section.

Product	Rachio 3	Hydrawise Hunter HC	Orbit B-hyve	BlueSpray	Conventional Irrigation System	QATra
Product Photo						
Cost	$228 - $232	$160 - $167	$50.50 - $62.19	$294.99 - $349.99	≈ $3000 - $4000 [15]	$541
Number of Zones	8 or 16	6 or 12	4 or 8	8, 16 or 24	Unlimited	Unlimited (additional cost will be added) *
Sensor Availability	None	Rain Sensor (add on) **	None	None	Rain Sensor (add on) **	Moisture Sensor
Weather Intelligence	Yes	Yes	Yes	Yes	No	No
Fault Detection	No (leakage only if flow meter was added) **	No (leakage only if flow meter was added) **	No	No	No	Yes
User Interface	IOS, Android and web browser	IOS, Android and web browser	IOS, Android and web browser	web browser	None	IOS Application
Preserving Water Resources	Yes, through Weather Intelligence	Yes, through Weather Intelligence or Rain Moisture level if Purchased	Yes, through Weather Intelligence	Yes, through Weather Intelligence	No	Yes, through Soil Moisture level Detection
Safety	Safe for Indoor and Outdoor if Purchased with a Waterproof Enclosure Case	Safe for Indoor	Safe for Indoor and Outdoor if Purchased with a Weather resistant cabinet	Safe for Indoor	Safe for Indoor and Outdoor (depending if the controller is water resistant or not)	Safe for Indoor and Outdoor
Promoting Smart Innovation	Yes	Yes	Yes	Yes	No	Yes
Raising Awareness	Yes	Yes	Yes	Yes	No	Yes

*Our prototype will contain only 4 zones. However, due to star network topology unlimited number of zones can be added.

**Those items are sold separately from the main product with additional cost.

2.4: Benchmarking Study Analysis:

- **Rachio3 VS. QATra**

Similarities:
Some of the common features that the Rachio 3 and QATra share is that they both can navigate the irrigation system through the mobile application. The user is able to turn off the system or change the water scheduling time accordingly. Also, both systems notify the user whenever the system starts watering the plants.

Differences:
When comparing the Rachio 3 with QATra, we can distinguish that for QATra irrigation system, the user does not need to specify the water scheduling times through the mobile application since the system contains soil moisture sensors that takes readings in time intervals to determine when the system is required to water the crop automatically. A feature of QATra irrigation system it that it notifies the user in case of any fault in the system such as faulty equipment through its mobile application and allows the user to view data of the soil moisture level from the sensors. Moreover, a unique feature that the Rachio 3 controller has is that it uses weather intelligence to determine priorly if any rain might occur in order to stop the system from irrigating. The Rachio 3 mobile application is supported for both iOS and android where QATra's mobile application is only supported for iOS. Furthermore, the Rachio 3 controller can navigate only up to 16 zones where as QATra irrigation system can navigate unlimited number zones due to its star network topology. For both systems prices differ depending on the number of zones.

- **Hydrawise VS. QATra**

Similarities:
Both Hydrawise and QATra enable the user to remotely control the irrigation system by adjusting the watering schedule or turn the irrigation system on or off. Also, both systems allow the user to monitor the irrigation process through a mobile application that provides information about the time and duration of each watering process.

Differences:

Comparing the Hydrawise and QATra irrigation system we can analyze that Hydrawise is an irrigation controller that waters the plants due to a watering schedule and watering duration provided by the user. On the other hand, QATra is a smart irrigation system that waters the plants according to their water needs due to the installation of soil moisture sensors. Weather intelligence is a feature included in Hydrawise, but it is not included in QATra. In Hydrawise, user can choose between web browser, IOS or Android application to interfere with the irrigation system, or even manually using the screen on the controller but in QATra there is only an IOS mobile application. In addition, the Hydrawise controller can navigate only up to 12 zones whereas QATra irrigation system can navigate unlimited number zones due to its star network topology. The price of each product differs due to different number of zones.

- **Orbit B-hyve Smart Wi-Fi Indoor Timer VS. QATra**

Similarities:
Some of the features that Orbit B-hyve Smart Wi-Fi Indoor Timer and QATra share is that they both can control the watering schedule of the crops by changing the times of the watering schedules through the mobile application. Also, the mobile application keeps the user up to date by sending notifications through the mobile application to inform when the system starts irrigation.

Differences:
Comparing the Orbit B-hyve and QATra irrigation system we can differentiate that QATra uses soil moisture sensors to measure the soil moisture level in order to determine whether the crops need watering according to a water level threshold. Hence, the system irrigates the plant automatically without a requirement from the user through the application but, the user is still able to interfere with the system. On the other hand, the Orbit B-hyve Smart Wi-Fi Indoor Timer has a smart watering feature where the user is required to input detailed information about the crops in order for the system to figure out the right amount of water for irrigation. Moreover, the Orbit B-hyve uses weather sense technology that receives local weather data and alter the controller's water needs based on the data to deliver the right amount of water to crops. Furthermore, the Orbit B-hyve does not take into consideration any fault detection of the system whereas QATra irrigation system notifies the user of any faulty equipment in the system. In addition, the Orbit B-hyve controller can navigate only up to 16 zones whereas QATra irrigation system can navigate unlimited number zones due to its star network topology (for both systems prices differ depending on the number of zones). The Orbit B-hyve mobile application is supported for both iOS and android where QATra's mobile application is only supported for iOS.

- **BlueSpray VS. QATra**

Similarities:
Both BlueSpray and QATra provide the users the ability to monitor and control the irrigation system through a user interface such as website or mobile application. The user can adjust and modify the watering schedules and follow up with the watering processes through the user interface.

Differences:
Comparing the BlueSpary and QATra irrigation system we can examine that BlueSpray irrigation system controller depends on the user's input of watering schedule and duration of crops. However, QATra uses sensors to identify the water needs of the plants and water it accordingly. Weather intelligence feature that is available in BlueSpray but not in QATra. Also, QATra irrigation system has fault detection feature which is not available in BlueSpray controller. Coming to user interface, user can control and monitor the irrigation system through website in BlueSpray controller, and through IOS mobile application in QATra irrigation system. The two products have different prices due to different features and number of zones.

After comparing different products to our design, it was concluded that our design fills the gaps of those products through implementing smart watering using moisture sensors, fault detection feature, and monitor the soil content and irrigation process through the mobile application.

Chapter III: Functional Modeling

3.1 Detailed Block Diagram Representation

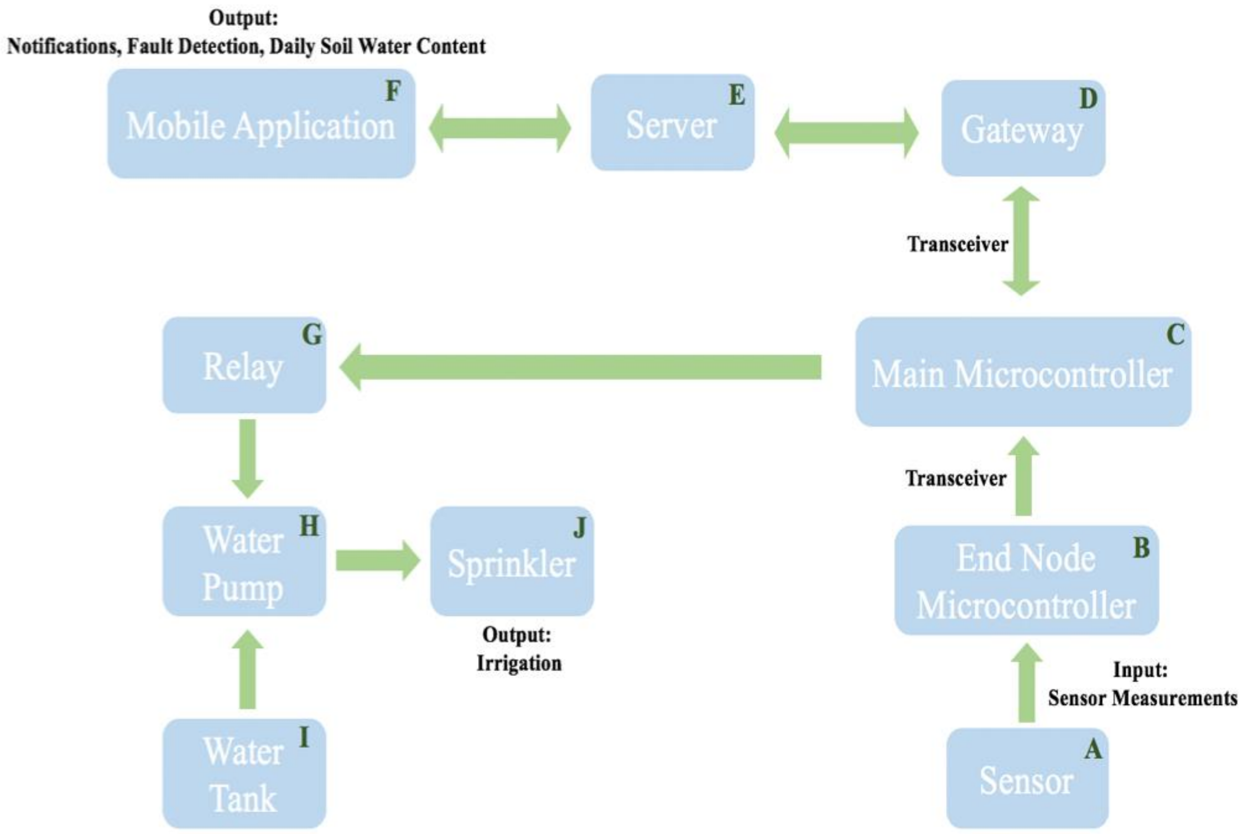

Figure 3.1: Detailed Block Diagram of Our System

3.2 Decomposition of Block Diagram Functions

Sensor (A) - End Node Microcontroller (B) Connection:
Each soil moisture sensor is paired with a small end node microcontroller. The sensor has a wired connection with the microcontroller. Each microcontroller-sensor pair (we have a total of 4 pairs in our prototype) is placed near the root zone of the plant. Each sensor will be responsible for measuring the soil moisture of a specific portion of the agricultural land (where it will have certain sprinklers responsible for it). This is done to have control over individual sections of the whole agricultural land. The job of the end node microcontroller is to take the soil moisture readings that are measured from the sensor to the main microcontroller.

End Node Microcontroller (B) - Main Microcontroller (C) Connection:
The end node microcontroller transmits the data gathered from sensor to the main microcontroller. The data is transmitted using a transceiver which follows the ZigBee protocol. Zigbee follows the IEEE 802.15.4 standard used to establish a wireless sensor network. This standard will be further discussed below. The main microntroller's job is to compare the soil moisture level with a specific

water threshold level. If the moisture level is below the minimum water threshold level, then the main microcontroller will run the watering system (connected to the sprinkler) to irrigate the plants. However, if the water level was above the maximum water threshold level then the main microcontroller will not allow the irrigation of plants. The details of the communication between the main microcontroller and the water system will be further discussed below.

Main Microcontroller (C) - Gateway (D) Connection:
The main microcontroller communicates with the gateway by sending data of the soil moisture sensor using a transceiver which follows the ZigBee protocol. Zigbee follows the IEEE 802.15.4 standard used to establish a wireless sensor network. This standard will be further discussed below. The purpose of the gateway is to continuously update the mobile application with the data collected. The gateway can receive instruction from the application (user) to interfere with the system in which the gateway will communicate back to the main microcontroller. This will be further discussed below.

Gateway (D) - Server (E) Connection:
The gateway communicates with the mobile application through a server. The server is a software platform or hardware device that organizes the networking between the two devices. The server responds to or receives requests from the client (user application).

Server (E) - Mobile Application (F) Connection:
The server sends data and receives instructions from the mobile application continuously. This includes soil moisture readings or notification related to fault detection (where it informs the user about a potential problem). The mobile application will be the client of the server. Also, the user can control the irrigation system through the mobile application, which will communicate back to the server (server-to-gateway and then gateway-to-main microcontroller).

Main Microcontroller (C) - Relay (G) Connection:
The main microcontroller will have the moisture level readings and if minimum threshold is reached the main microcontroller will turn the relay switch on. The relay is an electrical on/off switch used to control the water pump. Once the relay is turned on according to the threshold value from the microcontroller, the pump will supply water to the system. The input of the relay switch can come from end nodes (automation) or from the user through the mobile application (control). This will result in controlling the flow of water.

Relay (G) - Water Pump (H) Connection:
The relay will switch the water pump on or off depending on the sensor reading or user's command using the mobile application. In our prototype, there will be four relays and four water pumps. This was done because of the feature that allows each water sprinkler to be controlled individually.

Water tank (I) - Water Pump (H) - Water Sprinkler (J) Connection:
The water pump will be connected through a pipe network to the water tank on one side, and the water sprinkler on the other side. The water pump will receive the signal from the relay when it needs to be on or off. If it has to be on, it will pump water from the tank to the sprinkler. As mentioned above, there will be four water pumps, each of them will be connected to a sprinkler.

The sprinkler system which we ordered complies with ISO 9001 standard which is used for quality management systems. It will be further discussed in section 4.2.1.

Fault detection implemented in block diagram:
The faults of the system come from different parts of the system. Since the connection of the irrigation system is complex, fault can occur in more than one place and for several reasons so there is no exact or clear part of the system to pinpoint the fault. Therefore, it was discovered that it might be difficult to specify the fault component from certain parameters such as sensor readings over a period of time. Since the time to implement this project is a constraint, it was decided to notify the user of a potential fault in the system. This is important since it will keep the user up to date with the system by giving a warning that there might be a potential problem in the system and advise the user to check the system.

Chapter IV: Proposed Design

4.1: Detailed System Design

QATra is an advanced irrigation system that aims to reduce water consumption through controlling the amount of water being used in agriculture. A mobile application, where the user can view the daily soil water content, control the irrigation system, and get notified in case of a potential fault in the system. By using the mathematical, scientific and engineering concepts we were able to come up with the proposed design.

4.1.1: Overview of our design

Our proposed design is summarized below in **Figure 4.1**. Soil moisture level readings will be taken from end nodes (sensor-microcontroller pair) to the central node (another microcontroller). The sprinkler will turn on and off according to the threshold values. Data from end nodes will be transmitted using a wireless transceiver to the central node. Then the central node will take the readings to the gateway of the system and then to a server. Finally, moisture level data will be available in the mobile application for the user to monitor and control.

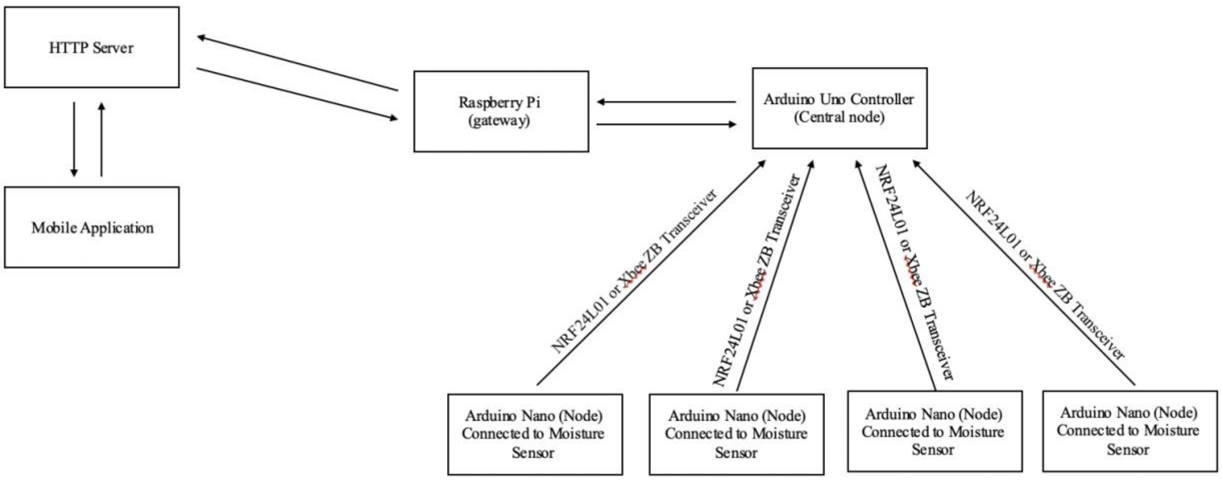

Figure 4.1: Wireless Sensor Network Proposed for our Project

4.1.1.1: Hardware Component Design

This irrigation system consists of moisture sensors, a controller and sprinklers. The scientific principle behind moisture sensor is soil resistivity measurements, which measures the conductivity of the soil. In order to effectively measure the level of moisture in the soil, the agricultural land is divided into regions. Each region has the same soil type, crop type and climate. Different moisture sensors are placed near the root zone, to get accurate readings of soil moisture levels as suggested by Mr. Osman due to his experience in agriculture. Those sensors will be connected to the controller. Using the controller, we will be able to manage when and for how long the sprinklers will run. The moist sensor will be taking data frequently. When the moisture level hits a minimum threshold, the sprinklers will turn on and when it reaches a maximum threshold, the sprinklers will turn off. If the moisture sensor detects a value that is higher than the threshold maximum, the sprinklers will not turn on (the case of a rainy day). Those threshold values will be taken from scientific sources such as Food and Agriculture Organization (FAO).

The sprinklers will be placed as shown in **Figure 4.2** below. Each sprinkler waters area around it. The distance between two sprinklers should be equal to the radius of the circle each sprinkler covers to ensure that the whole land is watered (there will be overlap of adjacent sprinklers) [14]. The sprinkler has a radius adjustment device. In this way one and/or more sprinklers can be set for a certain region. This will allow us to control the irrigation of each region using the app that will be discussed in the software component design section. Using mathematical knowledge gained, we will be calculating and analyzing area around sprinklers to minimize overlap between two nodes.

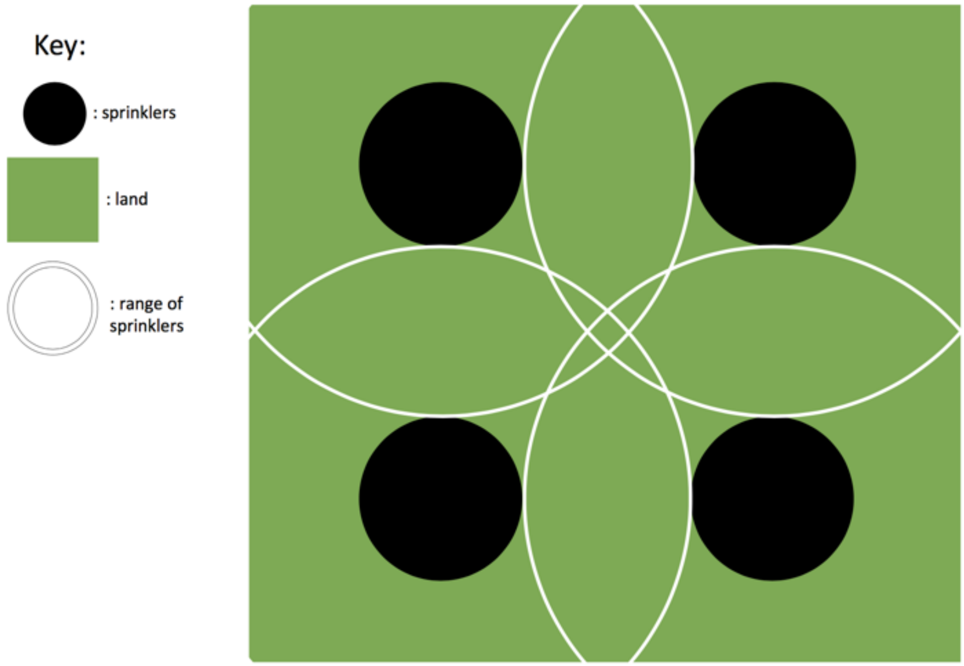

Figure 4.2: Placement of Sprinklers and Their Range.

4.1.1.2 Software Component Design:

With the fast growth of agriculture and the use of IoT, introducing an application software that accompanies the advanced irrigation system can help tremendously in real-time monitoring and controlling the irrigation system.

Using the sensors, physical quantities will be measured from the soil and transferred as electrical signals connected to the end node microcontroller. Our suggested and preferable topology is the star network topology as shown previously in **Figure 4.1** which is supported by Zigbee. For the star network topology, end nodes can be added without complicating the system. For the star network, end nodes will be connected to a central node. Each end node will have a transceiver that follows protocol which sends data to the central node. The central node also follows Zigbee protocol to send the data to the gateway through the transceiver, and then the gateway will update the app. Zigbee uses wireless communication which is and engineering principle to transmit and receive data from end nodes to the main microcontroller without a physical connection.

In order to send and receive data from the gateway to the app, the Wireless Area Network (WAN) can be used to establish a Transmission Control Protocol (TCP) connection. However, the user will have to be in the same Local Area Network (LAN), since the communication is limited to that area. The preferable suggestion is to use the HTTP server to communicate between the gateway and the Internet. This is a better two-way communication since the user can be outside the LAN in order to control the irrigation system. Both LAN and WAN are engineering principles used for the communication between the gateway and the mobile application.

This mobile application is used to keep records of soil conditions such as soil water levels, control the irrigation system, and reports when the plants are watered. As mentioned earlier, this application allows the user to interact and interfere with the irrigation system. Moreover, a vital feature of this application is that it notifies the crop owner by sending an alert of potential fault. This can be done by monitoring the measured soil moisture level every t minutes. In case that the moisture soil remains high, low, or constant for a long period of time, for different reasons i.e. water leakage, the user will be notified that there might be a potential fault in the system through the mobile application. It is important to note that the interval, t minutes, will be decided after various tests. Programming will be used to establish this algorithm which is an Engineering principle.

4.1.2: Design Components

4.1.2.1: Hardware components

The hardware components in our system include the physical equipment needed to establish WSN for the advanced irrigation system. WSN includes end nodes (sensor-microcontroller pair) with a sprinkler that is distributed in a field. It takes data from the sensors and sends it to the central/coordinator microcontroller. The wireless communication is done through the transceiver.

- **Sensors**
  Sensors convert the measured physical quantities to electrical signals that are then interpreted. Each end node will include a soil moisture level sensor used to measure the volumetric water levels in the soil.
- **Arduino microcontroller**
  The Arduino will be placed in each node to digitalize physical parameters and send them to the central/coordinator node (Raspberry pi) using the transceiver.
- **Raspberry pi gateway**
  The Raspberry pi is the gateway for the WSN. The Raspberry pi will interpret data by comparing it to the threshold value and it will send sensor parameters to the app using the transceiver.
- **NRF24L01 Transceiver**
  This is the wireless transceiver used to transmit and receive data from the node to the gateway.
- **Source/Battery**
- **A tank, pipes and sprinklers**
- **An iPhone to access the app**
- **Router**

4.1.2.2: Software components

The software will allow the hardware components to communicate with each other and/or with the computer. In the irrigation system, the system is programmed to allow two-way communication which will result in controlling and monitoring the water supply.

- **Arduino Integrated Development Environment (IDE)**
  The Arduino Uno is a programmable microcontroller, IDE is used to program, and it uploads it to the microcontroller
- **XCode:** IOS app developer
- **Linux/macOS for Raspberry pi**

The total price of our proposed design is $541. This price is not the final product price since building a prototype usually costs more than bulk production.

4.2: Existing Standards, Design Constraints and Risks

4.2.1: Existing standards

The two standards were used in our systems are the Zigbee which is an IEEE 802.15.4 [15] standard that is used to establish the wireless sensor network and the sprinkler system is bought from an ISO 9001 certified company.

1. Zigbee
    - The network topologies that Zigbee supports are: star, tree and mesh. Our suggested topology and the one we are planning to implement is the star network topology. The end nodes can be added in the star network topology, without further complicating the system. However, if the main microcontroller (central node) stopped working, there will be a problem in the system as the main microcontroller acts as a reference and it connects end nodes to the gateway. This happens to be a risk.

    - The most commonly used frequency bandwidth in Zigbee is 2.4GHz. The network consists of sensors, end nodes, central node, gateway and transceivers [15]. The transceiver is one of the main components of the network and is used to transmit and receive data up to a range of 100m [16] between end nodes and the main microcontroller. The distance range depends on the power consumption of the transceiver. We ordered two transceivers (NRF24L01 and Xbee ZB) for the project and both will be tested. We will be focusing on the range that the transceiver will cover. The range of the transceiver will depend on whether it's used indoors/outdoors. The range will depend upon whether obstacles are present and environmental characteristics. According to the range the best fit option will be chosen for the project.

2. International Organization for Standardization (ISO)

- The sprinklers and hoses have been ordered from Melnor, which is an ISO 9001 [17] certified company. This standard is for quality management systems. It ensures that the products actually contain the features that describes that particular product. This standard also ensures that the process quality is maintained so that the desired quality of the product is achieved [18].

4.2.2: Design Constraint

Resources constraint:

- We had an issue with determining where the sensors will be placed. We interviewed Osman Ahmed Abdalla (Agricultural specialist) to determine which placement gives the optimal soil moisture reading in order to achieve the best watering conditions. Osman explained that sensors must be placed near the root zone and that the root zone differs for different plant species, so it affects the level of soil depth for sensor placement.

- Moreover, the lack of knowledge and inexperience in farming increases the possibility of misinterpreting readings which can affect the whole irrigation system. This will require further exploration during the testing the sensors phase of our project.

Technical constraints:

- Ensuring well functionality of the application (user-friendly, free of defects and app complication) is crucial, especially considering that it is developed by beginners in app development. Therefore, we plan to test and simulate the application thoroughly (with advising from specialists and general people) to make sure it works properly.

- Ensuring that the distance between the end nodes or gateway and the main microcontroller is within the distance that the transceiver can transmit. If the distance is larger, then another microcontroller can be placed in between to shorten the transmission distance.

Environmental constraint:

- Depending on the geographical locations, weather and climate change can be very unpredictable. Heavy rainfall or dry weather can have an extreme effect on the soil moisture water level, where it can drive water level to be under soil water threshold or over the threshold. This constraint will be hard to tackle, since nature is unpredictable.

Health and Safety constraint:

- Part of the irrigation system consists of a water source (sprinkler) connected to electrical components (sensors and controllers). The combination of electricity and water can cause a dangerous hazard. Therefore, all electrical appliances will be in waterproof, transparent boxes.

Social constraint

- Many consumers or even farmers may not be acceptable towards smart and new innovative technology to be used is life's necessity such as agriculture. Therefore, it is important to raise awareness of how new technologies can be used for good (i.e reducing water wastage of irrigation).

Ethical constraint

- Ensuring that every process of our proposed design is complied with the IEEE code of ethics [19].

Economical constraint

- The cost of this advanced irrigation system to consumers is a constraint since our project is sold as a whole system (i.e with pipes, sprinklers, water pump, etc) rather than just an add-on device to current irrigation systems. Therefore, the initial price is higher however, with mass production the cost will reduce.

Political constraint

- There is no direct political constraint that is related to our project.

4.2.3: Design Risks

There are two main risks (what might go wrong) in our proposed design:

1. The main microcontroller
    - The main microcontroller is the main link between the end nodes, water system and the mobile application. If the main microcontroller stopped working then automation control of sprinkles will not be there anymore since it will not receive instructions from the main microcontroller, the application will stop receiving data from the sensor and the user cannot have control over the system. Overall, the system will stop working.

2. The Wi-Fi
    - The Wi-Fi is required in the system in order to send data or receive data from the mobile application. If the Wi-Fi connection was lost, then the user will not receive any data and will no longer have control over the system.

4.3: Link Between Our Project and ECEN Courses

ECEN 420: Linear Control Systems

In ECEN 420 course, Linear Control Systems, we looked at control systems; specifically, automatic control systems. A control system consists of a process/system and a controller. A system can be open-loop or closed-loop. A closed-loop system takes measurements of the output and has a feedback that compares those values with a desired output. An open-loop system has no feedback (the process is controlled directly). Our project will be a closed loop system, since measurements from the soil (moisture level) will either start the irrigation or stop the irrigation of the plants. The controller of the system is the main microcontroller and the process is the irrigation of the plants.

ECEN 449: Microprocessor System Design
This course taught us how to work with microcontrollers and how there are many types of processor used in the microcontroller intended for different jobs. We learn different types of serial communication used in order to transmit or receive data and how to use and operate sensors. This is all very beneficial to our project because we have some background on how to connect our system together (i.e. sensors and microcontrollers) and be able to determine the flow of data transmitted. Also, we can get familiar with the data the sensor generates by looking through the datasheets.

ECEN489: Cyber Security
In ECEN489: Cyber Security we studied eight different network topologies with their advantages and disadvantages. Since Zigbee only support three of the studied topologies which are: star, tree and mesh, only those three were being considered. This helped us in the decision making of the network topology of our proposed design and the risk that might accompany that topology. This is helpful for the wireless connection between the main microcontroller (central node) and end nodes. We also got familiar with the main types of networks which are: Local Area Network (LAN) and Wide Area Network (WAN). With this we knew that the data from the irrigation system locally had to be transferred to the Internet in order for the user to monitor and control the soil moisture level.

Moreover, in ECEN489: Cyber Security, we got familiar with Transmission Connection Protocol (TCP) which is the connection between a server and a client. It can be used to establish two-way communication between the server and client. TCP ensures that data sent is sent in order, secure and error free. In order to make a network connection, TCP port number is needed (example: HTTP server uses TCP port number 80). Knowing the port number can help us in the programming stage. ECEN489 labs also made us familiar with uploading files into a server using a TCP connection. This is useful and made us understand the connection between the gateway, server and mobile application of our designed system. It made the understanding easier during the research stage since these concepts were being mentioned regularly in research papers. Then by combining the theory from ECEN489: Cyber Security and the research that was done, we came up with the proposed design.

ECEN 210: Computer Programming and Algorithms
There is an obvious link between our project and ECEN 210: Computer Programming and Algorithms. ECEN 210 course taught us the basics of computer programming in C language and how to build an algorithm to solve a specific problem. Thus, it is easy for us to program using C or any other language; since the basics of all programming languages are similar.
To build our prototype, we will have to implement knowledge gained from ECEN 210 to program different components of our design. For instance, the Arduino will be programmed using the C language, the Raspberry Pi will be programmed using Python language, and the mobile application will be programmed using Swift language. Also, to implement our fault detection feature, a well-developed algorithm should be written.

Chapter V: Progress, Timeline and Conclusion

5.1: Progress Made

Towards the end of this semester we started by looking at the hardware of the end node (sensor-microcontroller pair). As shown in **Figure 5.1** we got a temporary pot plant in order to test and simulate the soil moisture sensor. We first connected the sensor to the microcontroller by looking at the grove sensor datasheet in order to find the right wire connection for data transmission. Then using the Arduino IDE software, we wrote a small code as shown in **Figure 5.2** in order to obtain the values that the sensor generates. To view the values as shown in **Figure 5.3** we had to use PUTTY which is a free open-source terminal. Also, we figured out from the datasheet of the sensor generates different ranges that results from different water levels in the soil such as dry soil, humid soil and if the sensor was placed in pure water. These different ranges will help us in determining where the water level threshold lies, and this will be different for different types of plants.

Looking into our software part of our design, a simple interface for our mobile application, as shown in **Figure 5.4**, was built using XCode software. It is clear that the user will be able to view the soil moisture level of the soil, get notified in case of fault detection, and control the irrigation system. This is our initial design. However, the design of the application might be changed in the future.

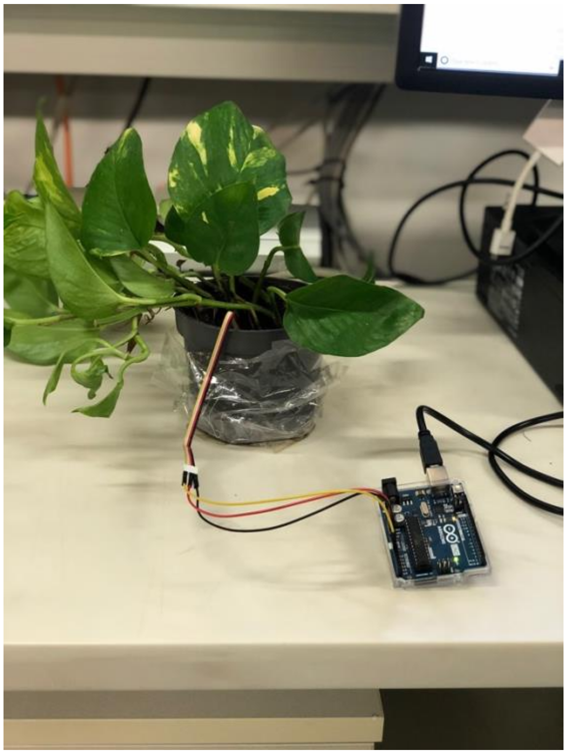

Figure 5.1: Microcontroller-sensor

Figure 5.2: Microcontroller-sensor pair

Figure 5.3: Sensor Results obtained through PUTTY

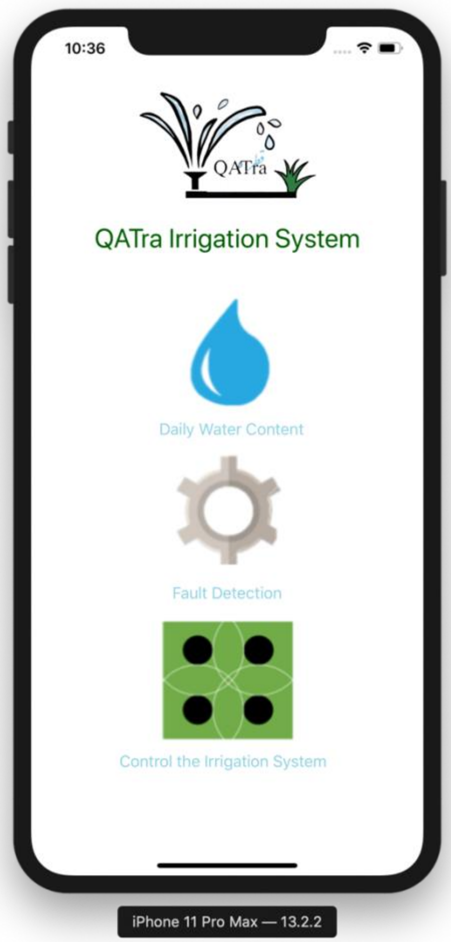

Figure 5.4: IOS Mobile Application of Our System

5.2: Project Timeline and Future Plans

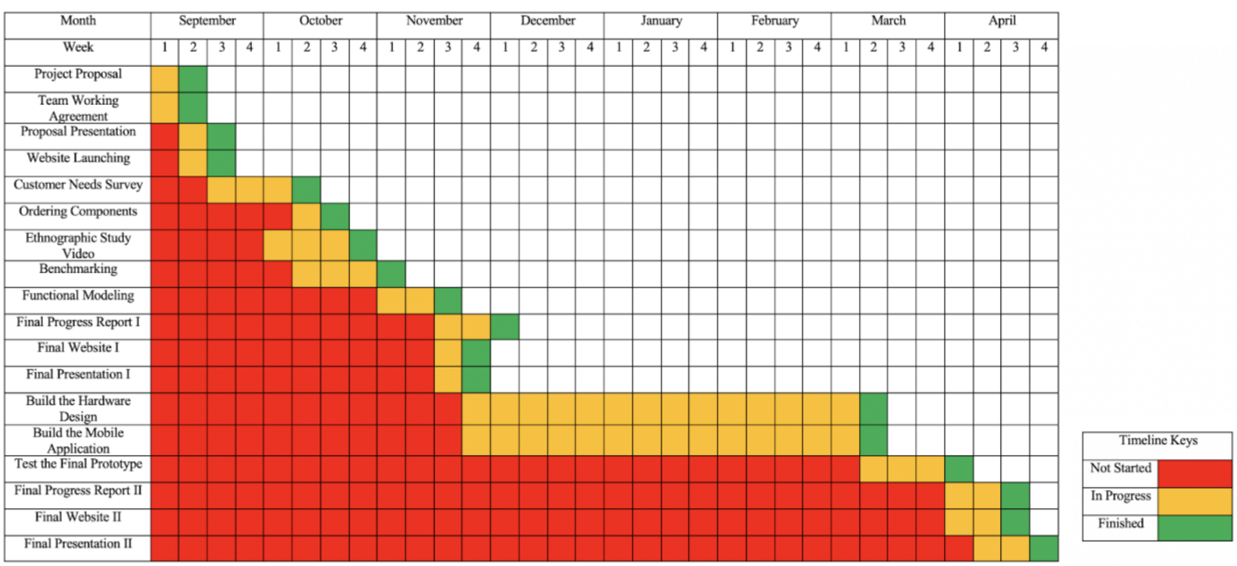

Figure 5.5: Timeline of Our Project

Figure 5.5 shows the progress that was made during the semester. It also shows next semester plans. It includes all of the assignments with the time required to accomplish those assignments such as benchmarking assignment. Our future plans include finalizing the mobile application and completing the hardware design. Also, testing the prototype is one of our main goals in the next semester. Finally, in April 2020, we plan to have a complete prototype of our proposed design.

5.3: Conclusion

We reached half the journey of assembling our senior design project. We came across many obstacles with coming up with the design and there were many advantages that helped us overcome those obstacles. Getting a deeper understanding on the products/research papers available, the publics' opinions, the experts' recommendations were tools that helped us fulfill the gaps in the design of our product. The work we did this semester helped us to get exposed to how the working environment can be.

The design that was discussed in this final report is different to the one we had in mind when we were discussing our product, which is all right, since, now, our product is not just a product that an engineer can design, but one that the market and society needs.

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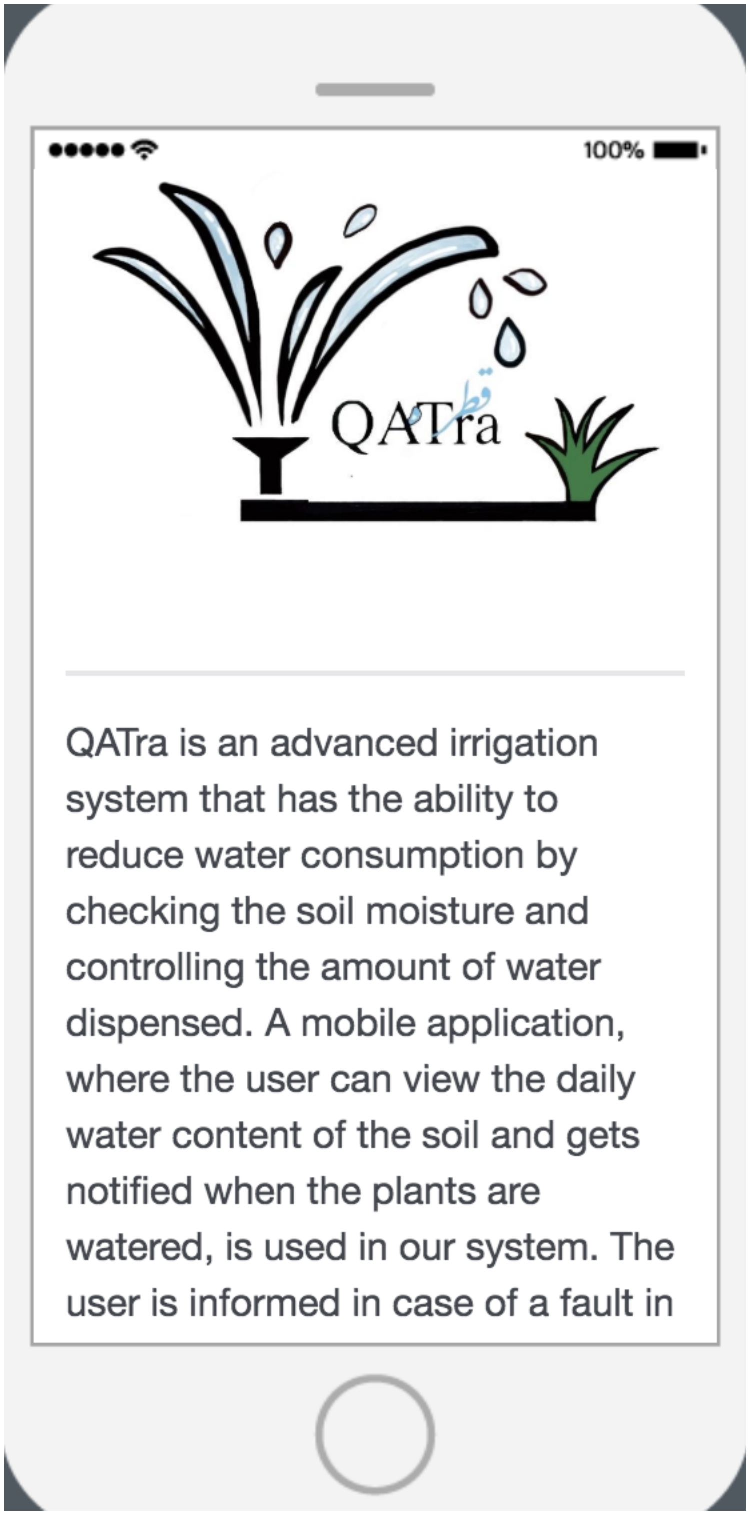
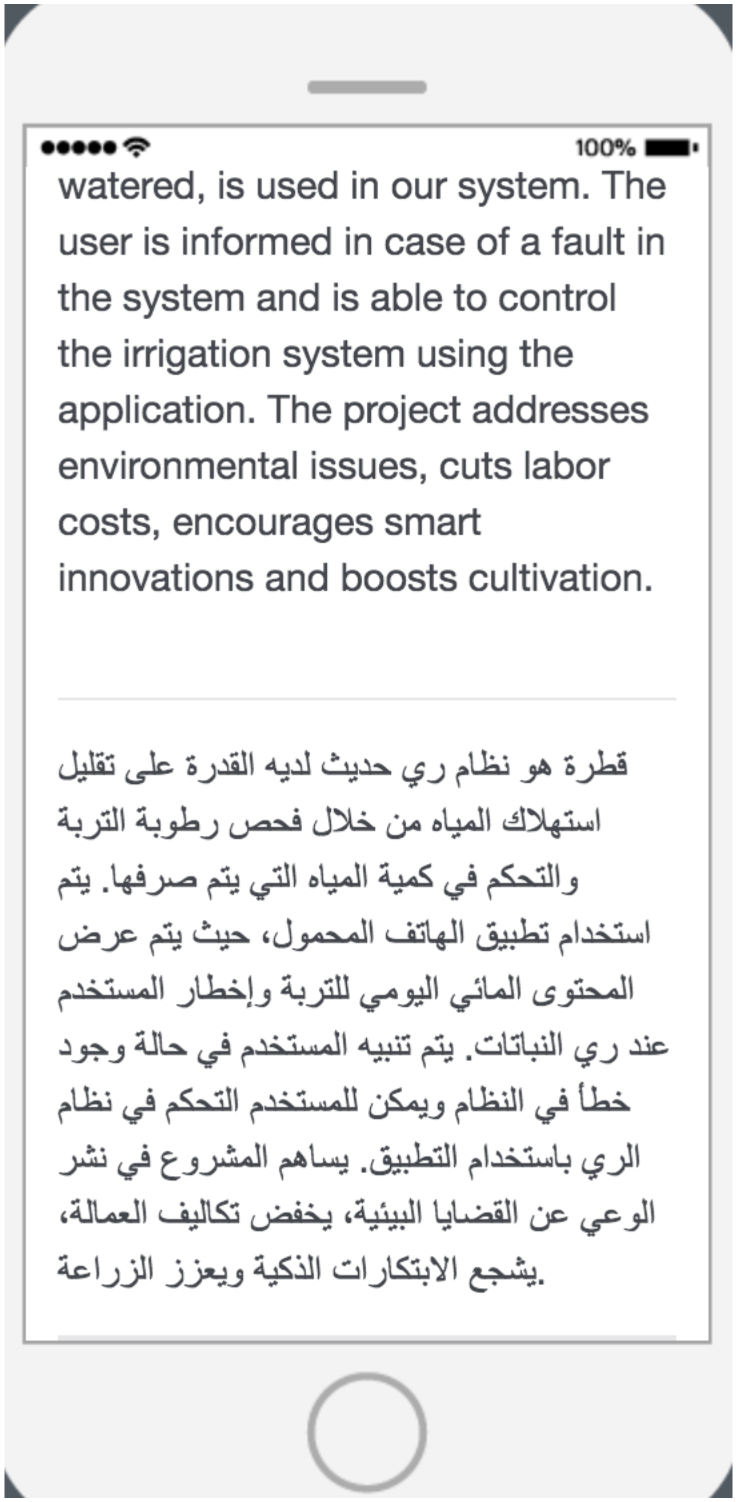
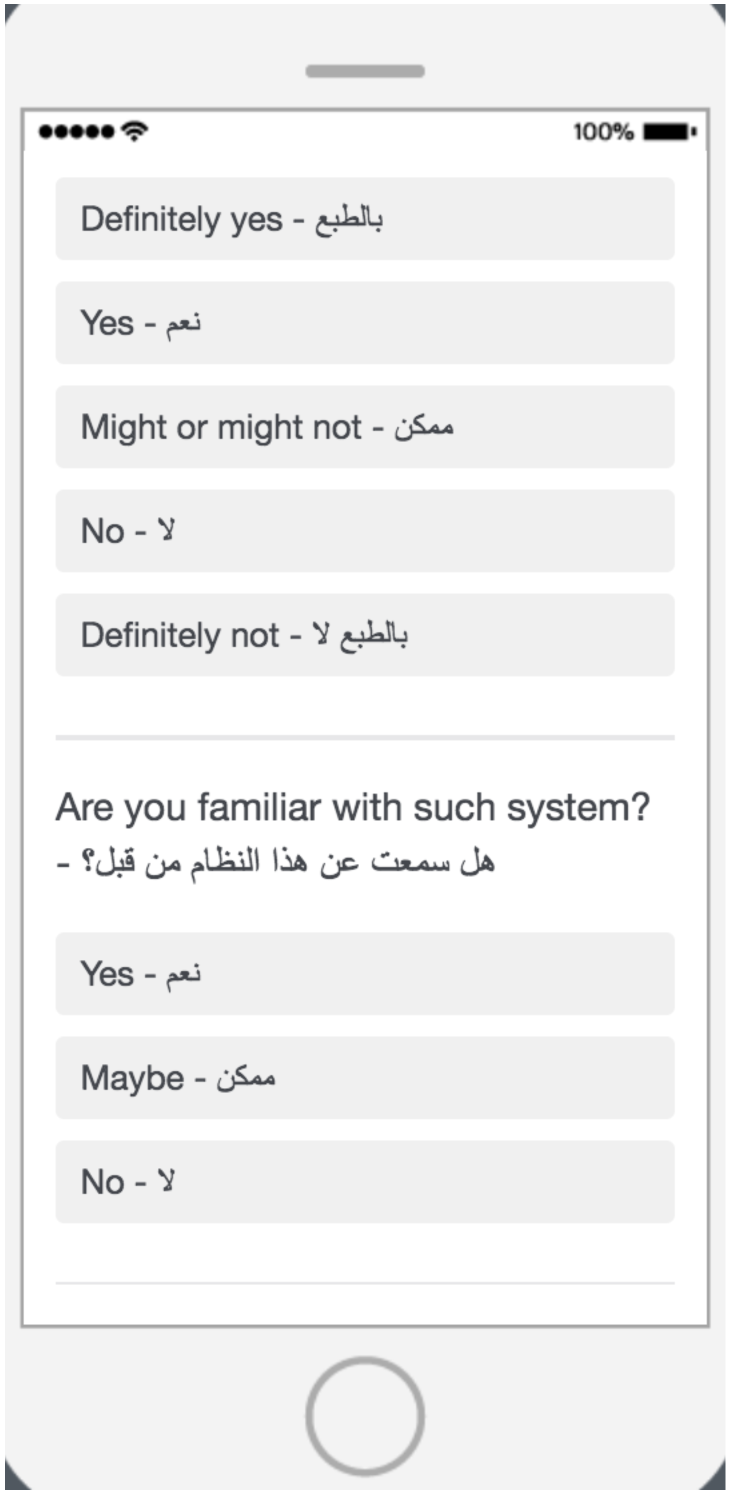
Appendix:

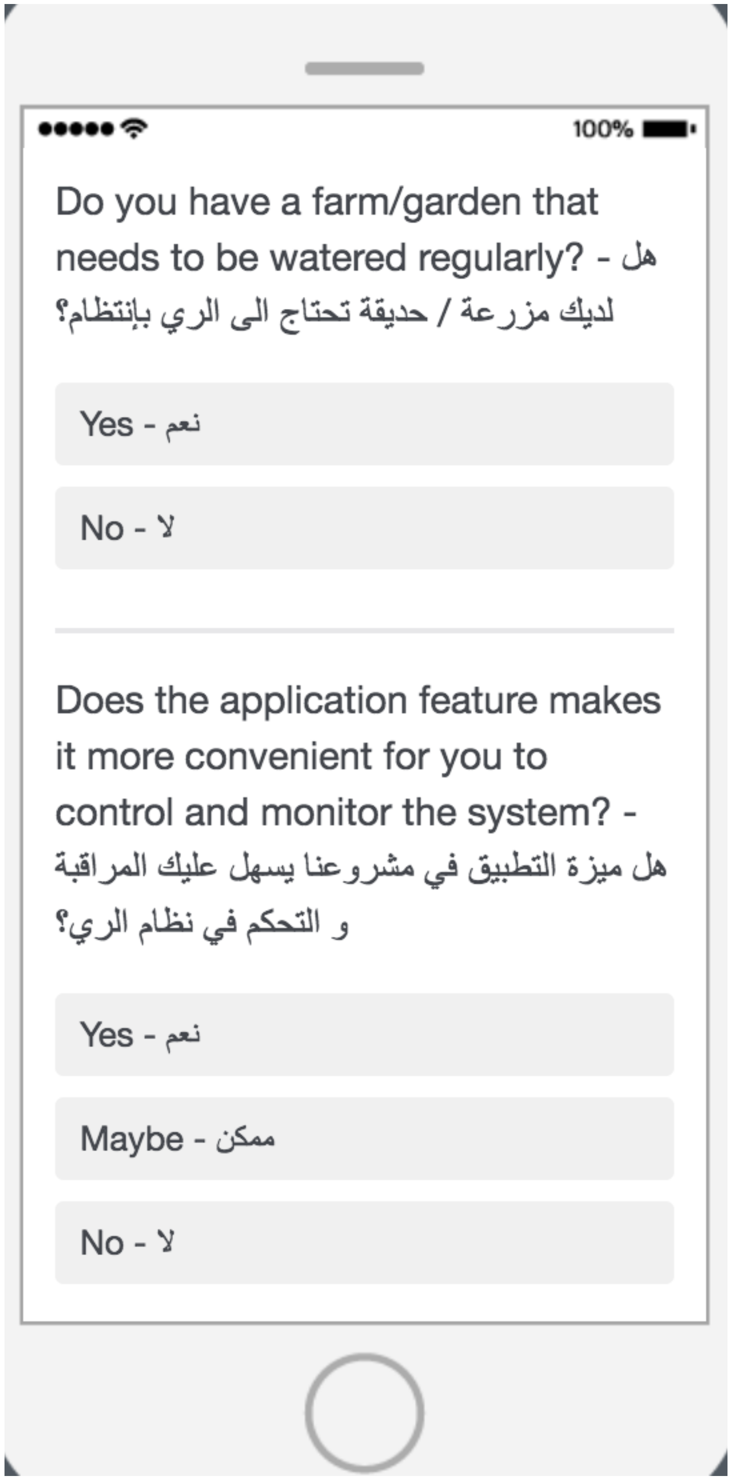
Survey 1: Questionnaire

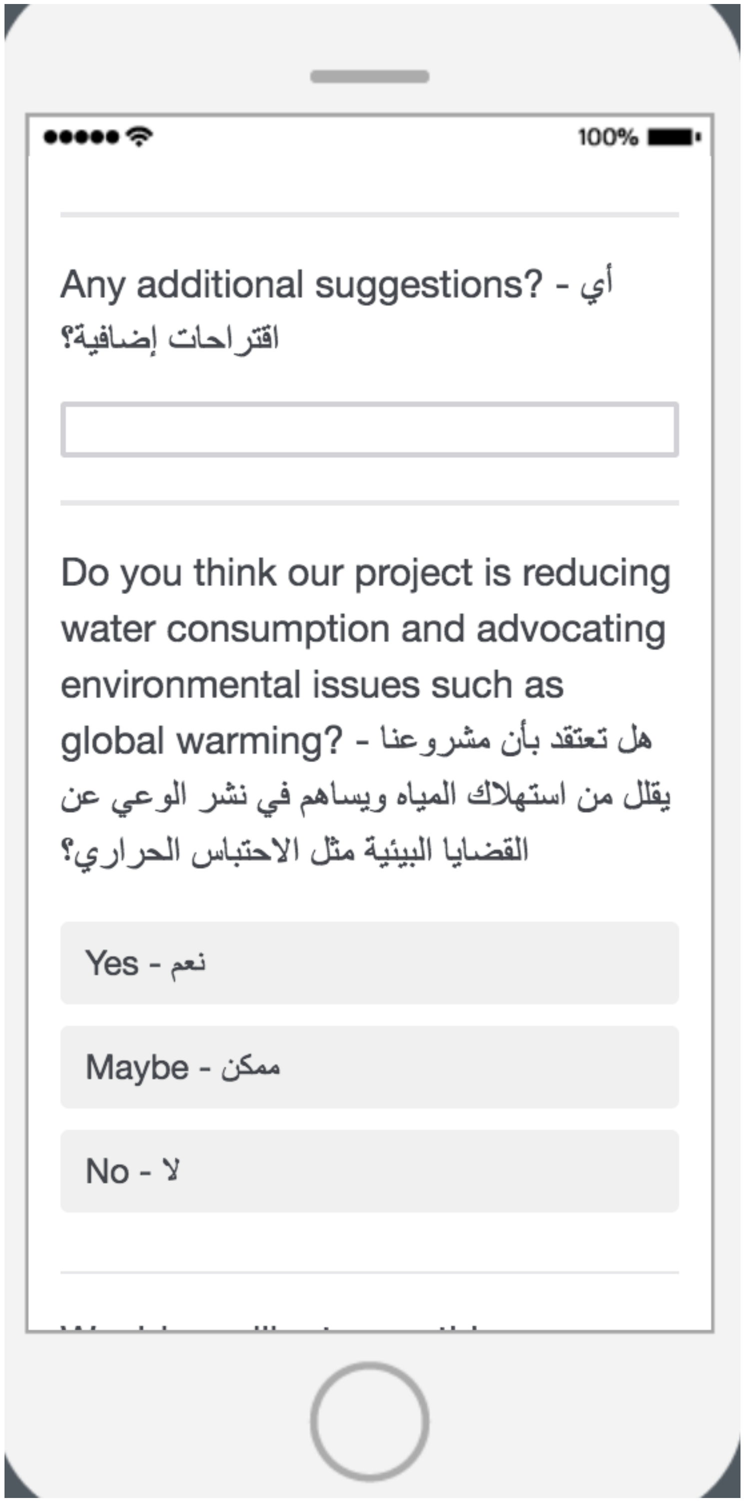


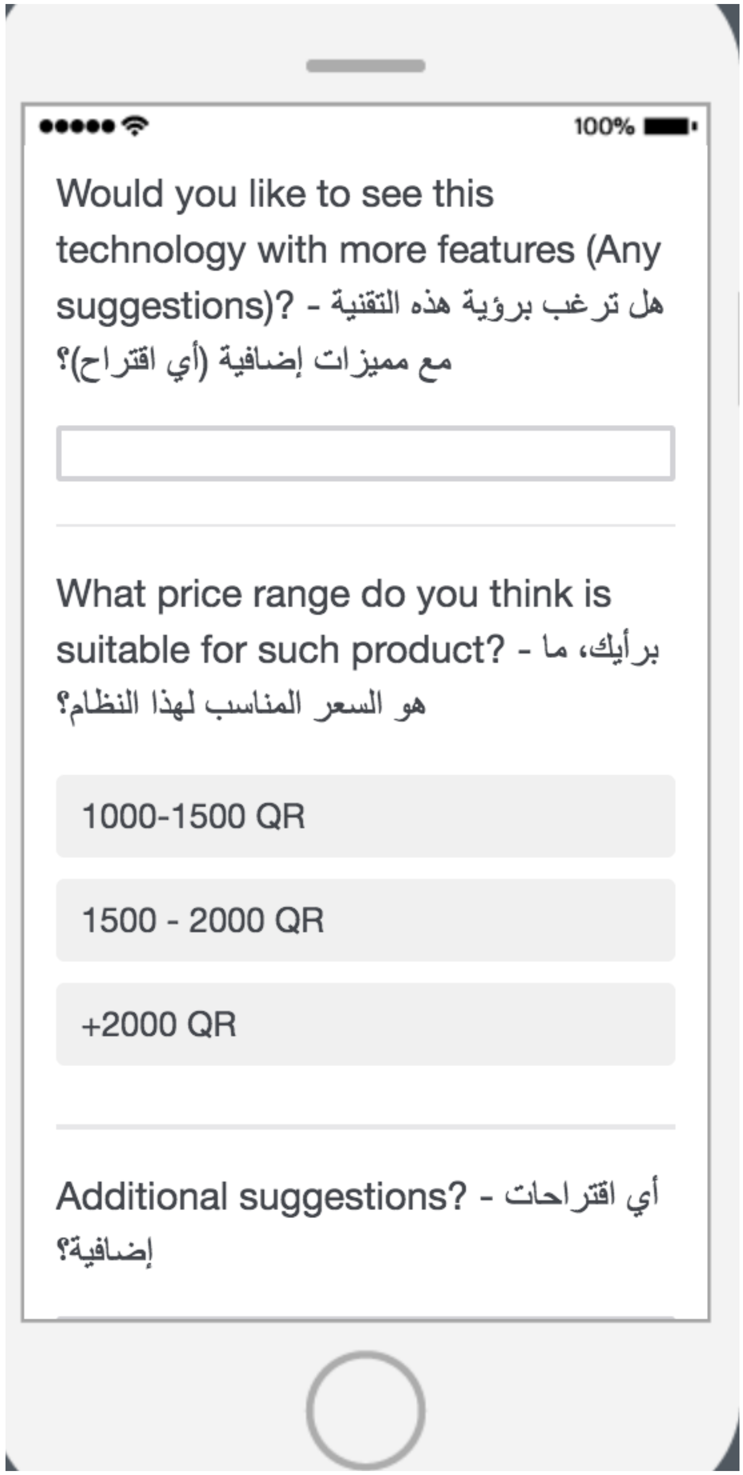

100%
watered, is used in our system. The user is informed in case of a fault in the system and is able to control the irrigation system using the application. The project addresses environmental issues, cuts labor costs, encourages smart innovations and boosts cultivation.
قطرة هو نظام ري حديث لديه القدرة على تقليل استهلاك المياه من خلال فحص رطوبة التربة والتحكم في كمية المياه التي يتم صرفها. يتم استخدام تطبيق الهاتف المحمول، حيث يتم عرض المحتوى المائي اليومي للتربة وإخطار المستخدم عند ري النباتات. يتم تنبيه المستخدم في حالة وجود خطأ في النظام ويمكن للمستخدم التحكم في نظام الري باستخدام التطبيق. يساهم المشروع في نشر الوعي عن القضايا البيئية، يخفض تكاليف العمالة، يشجع الابتكارات الذكية ويعزز الزراعة.


100%
Age Range - الفئة العمرية
Below 18 - اصغر من ١٨ سنة
18-25
26-35
Above 35 - اكبر من ٣٥ سنة
Gender - الجنس
Male - ذكر
Female - انثى
Will you be interested in a Smart Irrigation System? - هل انت/ي مهتم/ة في نظام ري حديث؟


100%
Definitely yes - بالطبع
Yes - نعم
Might or might not - ممكن
No - لا
Definitely not - بالطبع لا
Are you familiar with such system?
- هل سمعت عن هذا النظام من قبل؟
Yes - نعم
Maybe - ممكن
No - لا


100%
Do you have a farm/garden that needs to be watered regularly? - هل لديك مزرعة / حديقة تحتاج الى الري بإنتظام؟
Yes - نعم
No - لا
Does the application feature makes it more convenient for you to control and monitor the system? - هل ميزة التطبيق في مشروعنا يسهل عليك المراقبة و التحكم في نظام الري؟
Yes - نعم
Maybe - ممكن
No - لا


100%
Any additional suggestions? - أي اقتراحات إضافية؟
Do you think our project is reducing water consumption and advocating environmental issues such as global warming? - هل تعتقد بأن مشروعنا يقلل من استهلاك المياه ويساهم في نشر الوعي عن القضايا البيئية مثل الاحتباس الحراري؟
Yes - نعم
Maybe - ممكن
No - لا


100%
Would you like to see this technology with more features (Any suggestions)? - هل ترغب برؤية هذه التقنية مع مميزات إضافية (أي اقتراح)؟
What price range do you think is suitable for such product? - برأيك، ما هو السعر المناسب لهذا النظام؟
1000-1500 QR
1500 - 2000 QR
+2000 QR
Additional suggestions? - أي اقتراحات إضافية؟

Survey 2: Interview Questions

QATra Irrigation System Interview:

General Questions:

1. Are you familiar with a smart irrigation system? Will you be interested in it?
2. What is the feasibility/convenient/practicality of our proposed irrigation system?
3. What constraints do you think will be faced with our proposed irrigation system?
4. Do you think the application feature makes it more convenient for the user to control and monitor the system? Would you like to see the same technology with more features?
5. Do you think fault detection in the irrigation system is an important feature? Why?
6. Water is a scarcity in Qatar, do you think that our project will help in reducing wastage of water?
7. Do you think that there is scope for large scale implementation of our project in Qatar?

Specific questions for both:

1. What is the average cost of watering per square meter of land?
2. What do you think a suitable price for our project would be?

Specific questions for Kahrama:

1. Do you think that by implementing water threshold for various species of plants in our system will help in saving water/consuming less water? (If this system was implanted in small scale or large scale)
2. If this system is implemented will the cost of water reduce for its consumers.
3. Is the farming/agricultural industry consuming the most water?
4. Do you think that if our system was implemented and today's world adapted to this change of water control, then this will benefit the future generations? (In terms of water scarcity)
5. Will this project encourage the production of more ecofriendly systems that help save our environment?

Specific questions for Department of Agricultural research:

1. Are you familiar with a similar product? What feature does it have? Do you want to add any new features to it? Does it have any problems? Do you face problem while using it?
2. How much water does this product consume (per km^2)?
3. How much you are willing to spend on such system (per km^2)?
4. Where should the sensor be placed to get the most accurate results?
5. How often should we check for the moisture level in the soil?
6. Does the moisture level of the soil depend on the type of the plant? If yes, how should we know the desired moisture level for every plant?

Consent Forms of Interviewees

Consent form of Eng. Ahmed Shaker:

CONSENT FORM

Project: QATra Irrigation System
Texas A&M University at Qatar
Course: ECEN 403-Electrical Design Lab I
Group Members: Maryam Al-Emadi
Roqayya AlYousef
Fatima Al-Janahi
Noof Al-Sayed
Mentor: Dr. Hazem Nounou

I agree to participate in this interview for QATra irrigation system project. I also understand that I will be photographed/recorded/videotaped as part of the project and I agree to it without any pressure.

Name: Ahmed
Date: 3/10/2019
Signature:

Consent form of Eng. Ayman Mashali:

QATra

CONSENT FORM

Project: QATra Irrigation System
Texas A&M University at Qatar
Course: ECEN 403-Electrical Design Lab I
Group Members: Maryam Al-Emadi
Roqayya AlYousef
Fatima Al-Janahi
Noof Al-Sayed
Mentor: Dr. Hazem Nounou

I agree to participate in this interview for QATra irrigation system project. I also understand that I will be photographed/recorded/videotaped as part of the project and aware that this material will be used for assignments like the market analysis study, ethnographic study video and any upcoming assignment that might need this material.

Name: Ayman Mashali

Date: 14-10-2019

Signature:

Consent form of Eng. Mohamed Ben Aicha:

QATra

CONSENT FORM

Project: QATra Irrigation System
Texas A&M University at Qatar
Course: ECEN 403-Electrical Design Lab I
Group Members: Maryam Al-Emadi
Roqayya AlYousef
Fatima Al-Janahi
Noof Al-Sayed
Mentor: Dr. Hazem Nounou

I agree to participate in this interview for QATra irrigation system project. I also understand that I will be photographed/recorded/videotaped as part of the project and aware that this material will be used for assignments like the market analysis study, ethnographic study video and any upcoming assignment that might need this material.

Name: Mohamed Salah Ben Aicha // Project Engineer.

Date: 14/10 2019

Signature:

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Consent form of Mr. Osman Ahmed Abdalla:

CONSENT FORM

Project: QATra Irrigation System
Texas A&M University at Qatar
Course: ECEN 403-Electrical Design Lab I
Group Members: Maryam Al-Emadi
Roqayya AlYousef
Fatima Al-Janahi
Noof Al-Sayed
Mentor: Dr. Hazem Nounou

I agree to participate in this interview for QATra irrigation system project. I also understand that I will be photographed/recorded/videotaped as part of the project and aware that this material will be used for assignments like the market analysis study, ethnographic study video and any upcoming assignment that might need this material.

Name: Osman Ahmed EL Sharief Abdalla

Date: 14 OCT 2019

Signature: