# QATra Irrigation System

## Benchmarking Assignment

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

Group Members:
Maryam Al-Emadi
Roqayya AlYousef
Fatima Al-Janahi
Noof Al-Sayed
Mentor: Dr. Hazem Nounou
Course instructor: Dr. Ali Ghrayeb
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"An aggie doesn't lie, cheat or steal, or tolerate those who do."

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## 1. Introduction:

QATra is an advanced irrigation system which aims to reduce the overuse of water in agricultural lands and improve the efficiency of irrigation systems in Qatar; to achieve sustainable development and ensure a better life for future generations. Optimum use of our natural resources is a target that we have to look forward to. Our proposed design project is an advanced irrigation system that has the ability to save water wastage and avoid overwatering of crops. This is done by checking the soil moisture in order to control the amount of water being used. It advocates cultivation by making the process of watering plants easier through creating an environmentally and user-friendly mobile application. The mobile application allows the user to view the daily water content of the soil, control the irrigation system and manage watering schedule. Moreover, the user is notified when the automatic irrigation starts and if there is a fault in the system.

This report includes our proposed design solution, the existing solutions available in the market then compares those solutions to our design in order to identify the novelty of our proposed design and how it is different from the products in the market. Existing solutions are then compared in the benchmarking table according to benchmarking criteria which are technical criteria as well as specific considerations such as: public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. Finally, a benchmarking study analysis is done to summarize our findings.

### 1.1 Overview of our design:

Our proposed design is summarized below in **Figure 1.1**. 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.

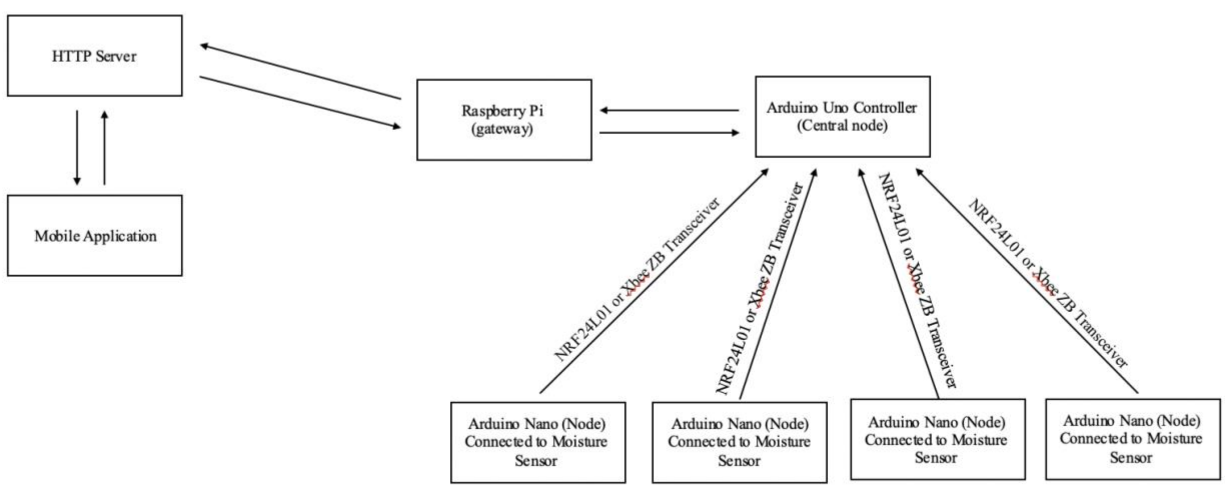


**Figure 1.1: Wireless Sensor Network Proposed for our Project**

### 1.1.2 Hardware Component Design:

This irrigation system consists of moisture sensors, a controller and sprinklers. 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 of each of the different regions [1]. 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).

The sprinklers will be placed as shown in **Figure 1.2** below. Each sprinkler waters a circle 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) [2]. 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.

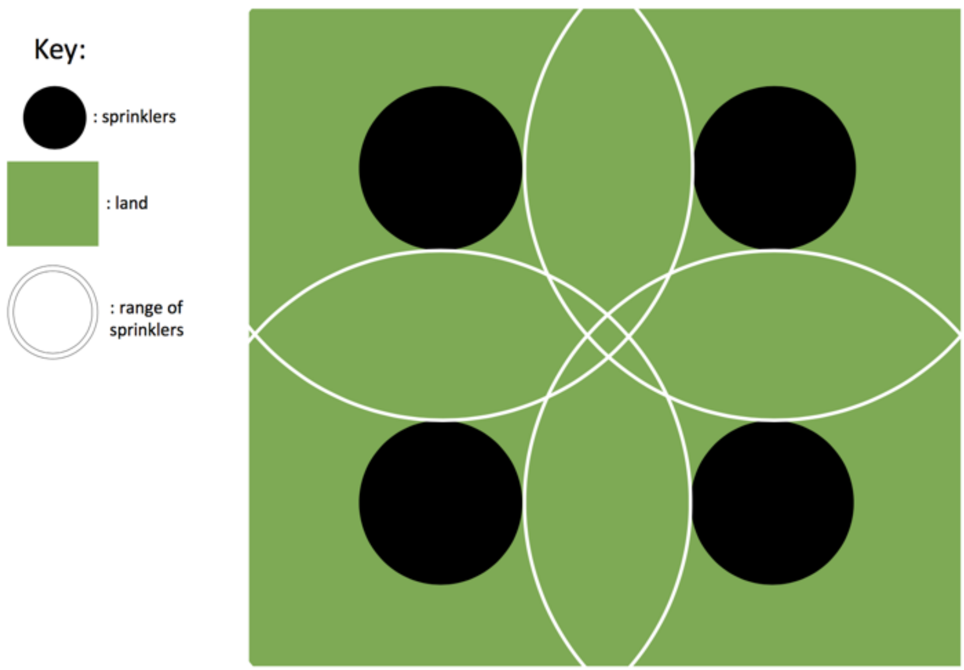


**Figure 1.2: Placement of sprinklers and their range.**

### 1.1.3 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 watering schedule.

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 1.1** 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.

In order to send and receive data from the gateway to the app, the Wireless Local Area Network (WLAN) 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.

This application is a resourceful way to keep records of soil conditions such as soil water levels, and watering schedule. It shows daily water content of soil and reports when the plants are watered. As mentioned earlier, this application allows the user to interact and interfere with the irrigation system. The watering schedule can be automatic as explained in the hardware component design section or the user can manually change the watering schedule of the crop and in case of a sudden climate (e.g. rainfall), the user is able to turn off the irrigation system.

Moreover, a vital feature of this application is that it notifies the crop owner by sending an alert of any faulty equipment. This can be done by monitoring the measured soil moisture level every t minutes. For detecting the faulty sprinkler, a value of low soil water level (below water threshold) is taken and compared with the soil water level of its consecutive interval of t minutes, if the water level in the soil remains low, then its concluded that the plants were not watered and hence the sprinkler is faulty. Therefore, a notification is sent straight away to alert the owner that a specific sprinkler does not work and needs repair. Detecting a faulty sensor occurs when the cloud server stops receiving values from that sensor for a period of time and so it sends an alert to repair that sensor. It is important to note that the interval, t minutes will be decided after various tests.

## 1.2 Existing Standards:

Zigbee is an IEEE 802.15.4 [3] based standard that is used to establish the wireless sensor network. Zigbee is a wireless radio network that supports the following networking topologies: star, tree and mesh. The commonly used frequency is 2.4GHz; its low power consumption and cost make it suitable for the irrigation system. The distance of Zigbee transmission can reach up to 100 meters [4]. It consists of sensors, end nodes, central node, gateway and transceivers [3].

## **1.3 Design Constraints:**

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.

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.

## **1.4 Design Components:**

To optimize the sprinkler irrigation system, it is vital to control as well as be able to monitor the usage of water. It is an automated system and the user will be able to monitor and control the sprinkler system through the app even if the user is in a different geographical location. In order to achieve that, the WSN protocol is used. The hardware and software components of the WSN for the advanced irrigation system are listed below.

### 1.4.1 Hardware components:

The hardware components in [5] 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**

### 1.4.2 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.

## 2. 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 Existing products:

**Rachio 3:**

The Rachio 3 smart sprinkler system [6] 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 [7] 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 [8] 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 [9] 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 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) [10] 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.

## 2.2 Literature review based on research papers:

In [11], the authors proposed the idea of smart irrigation system. 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 these 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.

In [12], the authors had an idea similar to that in [11] where they proposed using a smart irrigation system that consists of a controller which is connected to a moisture sensor and a water pump. The controller takes the measurement from the moisture sensor and decides 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.

In [13], the authors 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.

In [5] the authors have built an automated wireless irrigation system using a wireless sensor network (WSN) and embedded Linux board for collecting information from sensor nodes continuously, storing it in a database and then providing 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.

## 2.3 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.

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.

# 3. Benchmarking Criteria:

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 [14].

- Safety:
  Our project has a direct link to safety measures, where they have been taken into account in our design, as mentioned earlier, the interaction of water and electricity can cause a huge hazard and therefore all electrical appliances will be in waterproof, transparent boxes.

- 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 no link to cultural factors.

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

## 4. 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.

## 5. 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.

**6. Conclusion:**

QATra is an advanced irrigation system that aims to limit the amount of water being used in irrigation by checking the soil moisture level and watering the plants accordingly. A mobile application is used to help the user monitor and control the irrigation system, and is notified of the watering schedules and in case of faults in the system. Other irrigation systems have different designs. In order to understand our project better, we attained knowledge and got familiar with the current products on the market that are similar to our product. This can 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.

Certain criteria and considerations were taken into account in the comparison made. Those criteria were based on the technical details of irrigation systems and other factors than can have an influence on public health, safety, and welfare, as well as global, cultural, social, environmental, or economic factors.

Looking thoroughly on comparing the different products in terms of technical and non-technical criteria gave us insight on the criteria that distinguish one product over the others in this competitive market. This strategy is beneficial because it helped us to showcase that our design QATra included all of the main criteria. The objective of this assignment was met since we were able to explore and compare most of the criteria with the present products in the market.

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