QATra Irrigation System

Project Proposal

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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1. 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 the future generation. 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. Water is a precious commodity and has to be used wisely. This system will help in reducing the amount of water that is used in watering plants on a daily basis and thus helps in conserving water. Automated irrigation system will interpret the soil moisture level and activate the sprinkler accordingly to reduce wastage of water. The advanced irrigation system as a whole is easily accessible by the user through a software application. This mobile application can help the user to monitor moisture levels as well as manually control the sprinklers system. It can be used in agricultural land, where it will help reducing the cost of labor and provide a system that is cost-effective. It uses the Zigbee standard for creating a personal area network for secure communication. The following paper will discuss in detail the proposed design and components of our advanced irrigation system as well as address the different constraints that we might possibly face.

2. Introduction:

2.1 Motivation:

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 it's 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, as it has no rivers or lakes. However, there is one natural water resource which is groundwater that supplies the country with 62 million m^3 of water per year [1]. 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. So, Qatar started to desalinate around 540 million m^3 of seawater per year which is mainly for domestic usage and treat 330 million m^3 of 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 actually 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].

2.2 Problem statement:

Our 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 system. A mobile application, where the user can view the daily water content of the soil and get notified when the plants are watered, is used in our system. Moreover, the user can control the irrigation system by turning it off in case of expected rainy days and notifies the user in case of a fault in the system.

Our project has major advantages in many fields. First, it addresses environmentalist issues by its emphasis on reducing water consumption. Second, accompanied with the fact that our project is cost-effective, it will cut labour costs. Third, it will enhance the quality of living, since it will encourage smart innovations and enhance standards of living by boosting cultivation.

2.3 Outline:

The rest of the report consists of the proposed design, design components, estimated budget and justification, timeline and conclusion. The proposed design section will begin with a literature review that will present the available products and designs of different irrigation systems; later it will discuss the unique features that we will add in our system in the hardware component and software component design section. Moreover, the different constraints that we might face will be discussed. The design components will include the software and hardware components and their functions.

3. Proposed Design:

3.1 Literature Review:

As mentioned earlier, Qatar is facing a serious issue regarding water supplies. So, an advanced irrigation system is in demand to save a percentage of water wastage. Due to an increase in global warming, many researchers are contributing to increase the agricultural lands to reduce CO_2 emissions.

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.

In [6] 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 [7] the authors 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.

There are products that are available online which deals with smart irrigation systems. Rachio smart 3 is a sprinkler controller that allows the user to control the sprinkler from anywhere and plan a watering schedule using a mobile application and waters the plant with its need for water to avoid overwatering or underwatering. Also, it uses weather forecasts to avoid watering during rainy hours [8].

All of the researchers and companies 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.

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.

3.2 Hardware Component Design:

Our proposed design is to create an irrigation system that saves water, money and time. 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 [9]. 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** 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) [10]. 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 section.

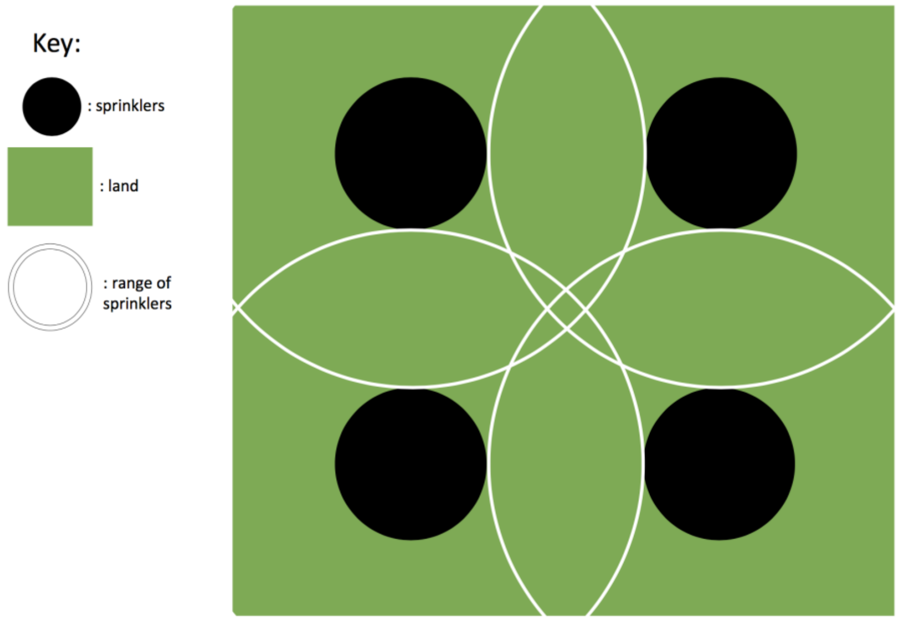


Figure 1: Placement of sprinklers and their range.

<u>3.3 Software Component Design:</u>

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. Thanks to the IoT, farmers or crop owners, can get immediate access and be able to communicate with their crops even from miles away.

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 in **figure 2** which is supported by Zigbee. 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 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: sensors or sprinklers. 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.

3.4 Standard Results:

Zigbee is an IEEE 802.15.4 [11] 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; it's low power consumption and cost makes it suitable for the irrigation system. The distance of Zigbee transmission can reach up to 100 meters [12]. It consists of sensors, end nodes, central node, gateway and transceivers [11].

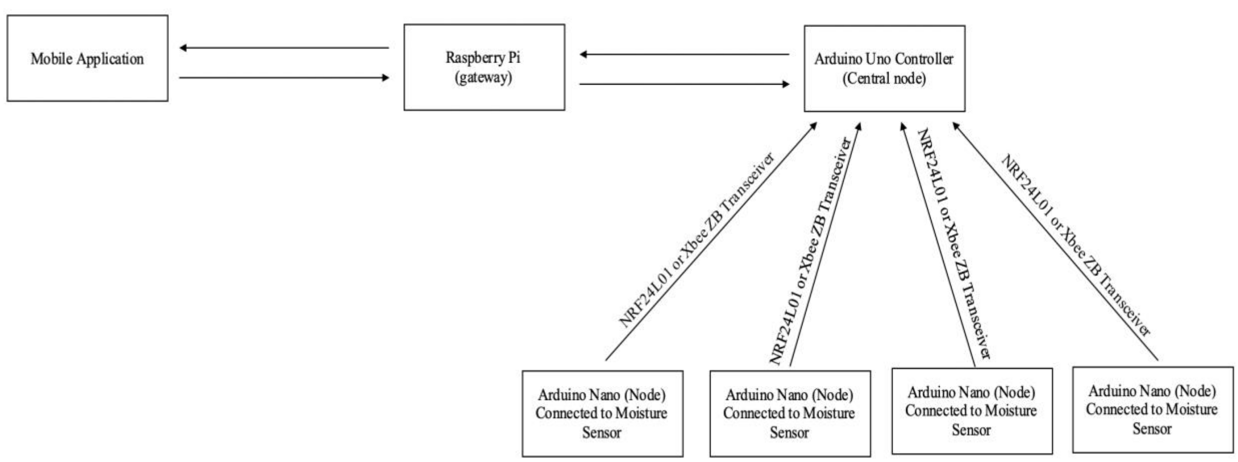


Figure 2: Wireless Sensor Network Proposed for our Project

3.5 Design Constraints:

Resources constraint:

- The physical placement of the sensors still requires further negotiations with specialists (for example: farmer/ agriculturist) to determine which placement gives the optimal soil moisture reading in order to achieve the best watering conditions. Similarly, the lack of knowledge and inexperience in farming increases the possibility of interpreting readings incorrectly which can affect the whole irrigation system.

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.

- We are using the star network topology in our irrigation system. Therefore, if the main microcontroller, which is connected to the rest of the microcontroller-sensor pairs, gets damaged then the communication of data transfer gets cut-off and so the whole system will stop functioning 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.

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.

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 Wireless Sensor Network (WSN) protocol is used. The hardware and software components of the WSN for the advanced irrigation system are listed below.

4.1 Hardware components:

The hardware components in [7] 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/Xbee ZB 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**
- **Wireless Local Area Network (WLAN)**

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 or Unity:** IOS app developer
- **Linux/macOS for Raspberry pi**

5. Estimated budget and Justification:

In this section, the budget of the design will be calculated using the estimated price for each of the suggested components. The components are classified into two major categories:

- Hardware Components:

- 4 × Moisture Sensor (Grove) = 4 × $5.90 = $23.60
- 4 × Arduino Nano Every: 5 × $9.90 = $49.50
- Arduino Uno microcontroller = $22.00
- Raspberry Pi = $35.00
- 5 × NRF24L01 transceiver = 5 × $1.2 = $6
- 3 × 4xAA Battery Holder Case Box DC Barrel Jack Connector for Arduino (Pack of 2) = 3 × $6.99 = $20.97
- 5 × Duracell Ultra Power Type AA Alkaline Batteries 4pcs = 5 × $5.5 = $27.50
- Tank (Arrow Plastic Slimline Beverage Container) = $7.26
- 4 × Water Sprinkler (Gesentur Lawn Sprinkler) = 4 × $10.34 = $41.36
- 4 × Arduino Water pump = 4 × $24.95 = $99.8
- 120pcs of Jumper wires = $6.49
- 4PCS Breadboards Kit Include 2PCS 830 Point 2PCS 400 = $9.86
- Router (Linksys WRT AC3200 Dual-Band Open Source Router for Home) = $191.74

Total estimated budget for hardware components = $541.08

- Software Components:

- Application development training course = $1000

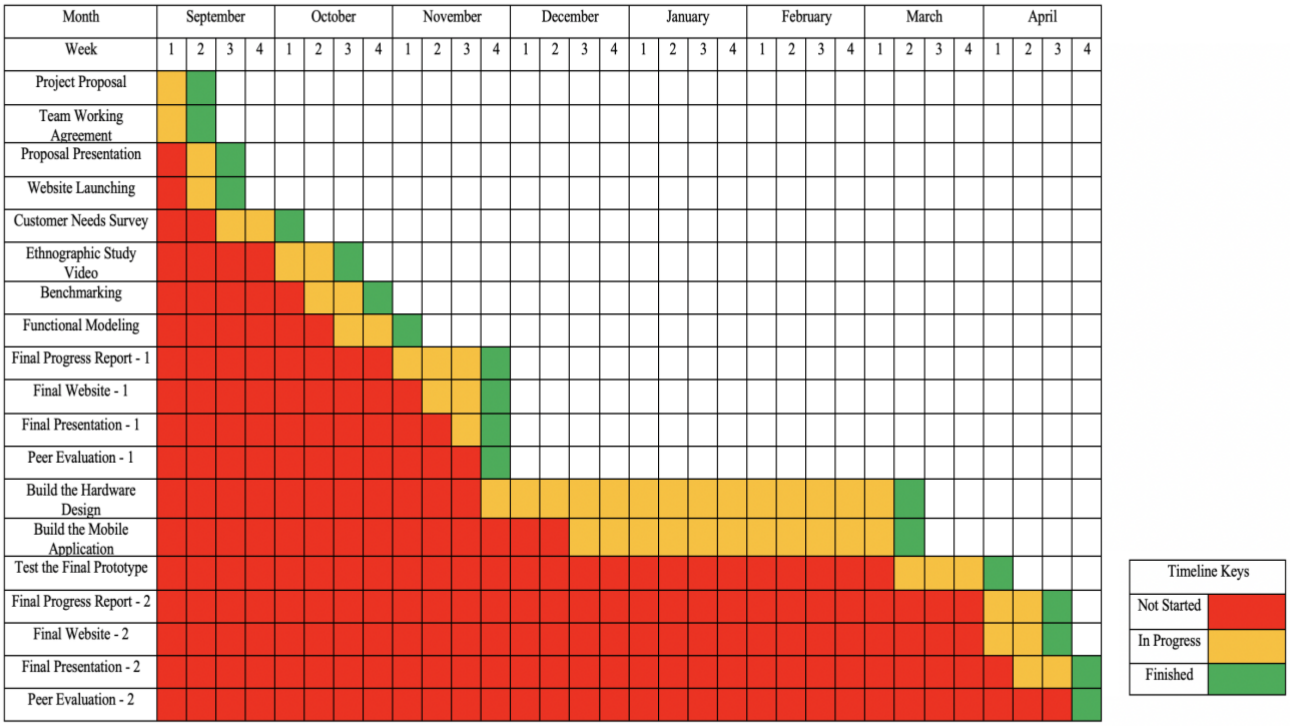
Total estimated budget for hardware components = $1000

Total estimated budget for our project = $1541.08

Justification:

The 4 moisture sensors, 4 Arduino Nano Every, and 5 NRF24L01 transceivers are needed to create nodes in order to develop a wireless sensor network that will be controlled by the Arduino Uno central node. Each of the 4 Arduino Nano Every and the Arduino Uno will have a power supply consist of 4 AA Alkaline batteries connected to it through the battery holder with a jack connector. Also, each node will have a single water sprinkler that can cover the area of the node which will be supplied from the water pump. The Raspberry Pi will be a gateway between the Arduino Uno central node and the mobile application.

6. Timeline:



7. Conclusion:

With the steady increase in population in the world, increasing the cultivation of agricultural land for food production is extremely important. This can be achieved by proposing an advanced irrigation system that promotes and advocates cultivation while aiming to save the environment by reducing water wastage. The proposed irrigation system is designed to avoid water wastage through monitoring the soil moisture levels and control the amount of water being used.

A mobile application allows the user to track moisture level activity to manage the irrigation system and get notified in case of a fault in the system. We aspire that the advanced irrigation system will encourage and influence people to develop smart and sustainable innovations to benefit the future generations.

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