AUTOMATIC REMOTE FARM IRRIGATION SYSTEM WITH WSN AND WEATHER FORECASTING

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Abstract. The paper showcases the system used for automating agriculture using wireless sensor network (WSN) and weather prediction. WSN, is more efficient than IoT as it avoids connecting all the sensor nodes directly to Internet, thus reducing the traffic over Internet and energy consumption of the sensor network. The system consists of a clustered tree topology to increase the range of operation, connectivity and easily connect new nodes dynamically. The sensor nodes being the leaves, local gateways being the branches and the global gateway being the root node. The system is implemented using cost effective micro-controllers, robust communication modules and reliable data showcasing platforms. Our implementation uses weather prediction to minimize the water needed for irrigation. Thereby minimizing cost and increasing efficient usage of resources.

1. Introduction

India, home to 136 Crore people, the second-most populous country in the world, requires a stable food supply chain. Agriculture plays a very important role. Irrigation is what keeps the show running. With the uncertainty in rainfall patterns, global warming and rising population the increase for water and other natural resources has risen considerably, which has become the reason for the rise of precision agriculture. Agriculture can be automated for providing a higher yield and can be handled remotely for farmer’s convenience. If the agricultural land is located far from the farmer then he can monitor the farm. Agriculture requires a robust system that can efficiently make use of water but to achieve this we need to implement wireless sensor networks, WSNs, which can monitor and control irrigation, a major aspect. It also gives information about the weather conditions and can detect intrusions. Thereby, they help maintain the moisture levels of soil which helps in having better crop production.

WSNs can be of two types one, above ground and second, underground. Various networking schemes and nodal architectures have been discussed and compared. Various case studies have been done to show the applications of WSNs [1]. WSNs have employed the MQTT protocol. MQTT protocol is lighter, simpler and more advanced than HTTP [2]. Implemented a cyber physical system consisting of soil moisture sensor and communication modules. The authors have highlighted the advantages of using RF transceiver modules over the other wireless technologies like ZigBee, WIFI and Lora [3]. The idea of Weather Prediction has been discussed, stressing on how production increases with the maintenance of proper moisture values [4]. Implementation of a temperature and motion detection system using the nRF24L01 module has been done. The authors have used 5 nodes, 4 sensor nodes and 1 base station. Each sensor node has a PIR sensor, Temperature sensor, and Arduino UNO and nRF24L01 module. They have adopted the star topology as addition of new sensors and removal of faulty sensors is easy. The data has been uploaded into Arduino web server. This paper gives us insights on the WSN using nRF24L01 transceiver module [5]. The sensor node components, working, setup has been explained and discussed. They have set up the sensor node using arduino, nodemcu, moisture sensor and intruder detection sensor. They have used an open source mobile application called blynk to transmit data from the sensor node to the mobile application of the user [6]. Adopted a WSN framework which is both low
cost and power efficient. They also have reiterated the fact how the two factors are decisive in the longer run [7]. Irrigating the farm based on soil parameters which is sent by the sensors to the control unit. The system can be remotely controlled with mobile application [8]. WSN is an efficient way of producing and managing crops on the farm. Agriculture, which is based on several factors, WSN can be used to manage various parameters [9]. Soil parameters along with the nutrient levels can be maintained with the help of WSN to carry on agriculture in a scalable way [10]. Soil parameters along with the nutrient levels can be maintained with the help of WSN to carry on agriculture in a scalable way, in a greenhouse [11]. Soil moisture varies with weather conditions like atmospheric humidity, soil and atmospheric temperatures. Analysis and understanding of variations in soil moisture according to these factors is done in this study [12]. Soil moisture, pH and weather updates are taken into consideration for fertilizing and watering the crop. Webscraping applications are employed for getting the type of crop and weather updates [13]. K-Nearest neighbor method is used to overcome the over-fitting problem caused by SVM and K-mean, and proposed a system to fully automate irrigation with predefined data collected over three weeks [14]. FC-28 sensors are used to collect the moisture content in the soil and that data is sent to cloud with the help of Node MCU’s and the servo motor is controlled automatically. All these are integrated by considering star and multi-hop topologies [15].

Our model can configure the wireless sensor network dynamically, we can accommodate new sensor nodes by adding the new sensor node ID in the gateway node program. Using the tree topology, we can accommodate a network of 3125 sensor nodes as nRF24L01 can have a set of six parallel data pipes. Unlike the IoT model where we connect each sensor node to the Internet, our model connects only the gateway node to the Internet thus reducing the data flow over the Internet and also reducing the power consumption, as WiFi modules consume more power than nRF24L01 modules.

Section 2 describes some previous works related to different aspects in a WSN Irrigation system. Section 3 describes the methodology employed to accomplish the task at hand. Section 4 Results based on the working of remote farm irrigation system with WSN and weather forecasting system are described. Section 5 deals with the conclusions made on the study, implementation of the project and the future work that can be accomplished.

2. Related Work
In the area of precision agriculture using modern communication technologies there has been a lot of work done to assist the farmers and improve the yield. In [3] implementation of a cyber physical system to monitor and irrigate the farm is done, controlling and monitoring the farm according to the weather conditions can be added. Maintaining proper soil moisture according to the weather conditions increases yield [4]. In [6] the working of a sensor node with weather prediction is done, but they have not used the sensor network model, if we had to deploy in a large field each sensor node has to get connected to Wi-Fi, Wi-Fi modules consume lot of power compared to nRF modules. Weather conditions play a crucial role in controlling the soil moisture and soil temperature thus controlling the yield and growth of the crop, by using current technologies we can make agriculture to smart agriculture [12].

3. Methodology
To monitor the change in the physical environment sensors are used. To collect and send the updates about the changes in a wider environment these sensors are deployed spatially to form a wireless network using communication modules, these sensor networks are called wireless sensor networks. For developing a WSN, which can monitor and irrigate the farm, at the sensor nodes, we have used soil moisture sensors and for detecting the intruder, we have used passive infrared (PIR) sensor. As shown in figure 1, each sensor node consists of three main subsystems namely – Sensing/actuating subsystem, control subsystem and communication subsystem. In our system at each sensing/actuating subsystem consists of a soil moisture sensor, PIR sensor and a solenoid valve. The control subsystem consists of
Arduino UNO and the communication subsystem consists of nRF24L01 transceiver module. The nRF24L01 transceiver module works in 2.4 GHz ISM band. It can communicate through 125 channels with 1 MHz spacing between them. At any point of time, each nRF24L01 can listen up to six other modules. To avoid interference we can use different channels. To accommodate more sensors we can form a tree topology, with 5 children nodes for each sensor node and these parent nodes relay the information to their parent node in hierarchy and finally all this information is relayed to the gateway node. The power consumption of the nRF24L01 modules is less than that of a LED, which is around 12 mA at 0 dBm and in standby mode it is around 26 µA. Consuming such less power makes this module very useful for low power applications. At the gateway node we have used Node MCU, it is a microcontroller unit and has an inbuilt ESP8266 Wi-Fi module to readily connect to the Internet. When the Node MCU is interfaced with the nRF24L01 module, it can be connected to the WSN of the farm. Thus, Node MCU can be used as a link between the Internet and the farm sensor network. Node MCU collects the weather information from the OpenWeather API through the Internet and the sensor data through the farm WSN it process the data, make out decisions according to the data received, uploads the data to the ThingSpeak through Internet and actuates the solenoid valve if necessary. Information about the weather is taken from OpenWeather with a unique API key. The gateway node sends a HTTP get request, which specifies the location’s latitude and longitude. MathWorks provide the cloud platform ThingSpeak, it allows us to aggregate, visualize, and analyse live data streams in the cloud. The data can be further be used in MATLAB for analysis of the water demand of the crop. The write API key is stored in the gateway node and it updates the information through this key. There are many android applications, which can read the information from the ThingSpeak through read API key and display the information to the user. We have used ThingView – ThingSpeak viewer to display the farm parameters in the user mobile phone.

The soil moisture gives output in the form of 10-bit ADC ranging from 0 to 1023. For zero moisture it returns 1023, in open air. As we are working in agriculture, we need only values between completely dry soil and full wet soil so we need to calibrate the soil moisture sensor accordingly. For easy controlling and understanding of the farm conditions, it is better to convert the soil moisture into percentage. Using equation (1) we can convert the obtained soil moisture sensor value into percentage

Let,

Dry soil moisture = $SM_{dry}$
Wet soil moisture = $SM_{wet}$
Measured soil moisture = $SM_{mes}$

Now we need $SM_{mes}$ in percentage within the range $SM_{dry}$ and $SM_{wet}$

Soil moisture in percentage = $SM$

$$SM = \frac{(SM_{mes} - SM_{dry}) \times 100}{SM_{wet} - SM_{dry}}$$

(1)

From the obtained SM values, the optimal soil moisture can be determined in terms of percentage and can be set as $SM_{max}$, for this study we have taken 70 percent. Depending on the farm conditions in the farm the $SM_{min}$, $SM_{mid}$ can be determined. $SM_{min}$ stands for minimum soil moisture that can be maintained in farm, $SM_{mid}$ stands for medium soil moisture that will be maintained during cloudy
conditions and $S_{M_{\text{max}}}$ stands for maximum soil moisture that will be maintained in the farm after irrigating. All the three parameters - $S_{M_{\text{min}}}$, $S_{M_{\text{mid}}}$ and $S_{M_{\text{max}}}$ are varied according to the crop; for our implementation we used 30, 50 and 70 percentages respectively. MS stands for motor state. All the parameters SM, $S_{M_{\text{min}}}$, $S_{M_{\text{mid}}}$, $S_{M_{\text{max}}}$, cloudiness and humidity are in percentages. The PIR sensor gives output "1" whenever there is change in the environment around it. Thus being active and giving an alert only when there is an intrusion. Figure 2 shows the setup at the gateway node, where the Node MCU is connected to the nRF24L01 transceiver module. Figure 3 shows the setup at the sensor node, where the nRF24L01 transceiver module, soil moisture and PIR sensors are connected to the Arduino UNO micro controller.

3.1. Algorithm for Gateway
(i) Initialization of SM, $S_{M_{\text{min}}}$, $S_{M_{\text{mid}}}$, $S_{M_{\text{max}}}$, MS, cloudiness and humidity
(ii) Connect to the WiFi
(iii) Get Data from open weather map
(iv) Setting up of nRF Channel
(v) Initialization of channel, channel available
   (a) Yes? Go to (vi)
   (b) Else? Wait
(vi) Read the data from sensor nodes
(vii) Check for conditions
   (a) $S_{M} < S_{M_{\text{min}}}$?
      1. Yes? Go to (b)
      2. No? MS=0
   (b) Cloudiness < 90 and humidity < 75?
      1. Yes? Go to (c)
      2. No? Go to (d)
   (c) $S_{M} < S_{M_{\text{max}}}$?
      1. Yes? MS=1
      2. No? MS=0
   (d) Cloudiness > = 90 or humidity > = 75?
      1. Yes? Go to (e)
      2. No? MS=0
(e) SM < SM_{threshold}?
   1. Yes? MS=1
   2. No? MS=0

(viii) Update the data to ThingSpeak
(ix)  End

3.2. Algorithm for Sensor Node
(i) Setting up of nRF Channel
(ii) Initialization of channel, Channel available
      (a) Yes? Go to (iii)
      (b) Else? Wait
(iii) Read sensor data
(iv) Append device ID
(v) Display on demand
(vi) End

4. Results

Figure 4. Scenario 1.

As shown in the figure 4. Scenario 1, explains the case where the soil moisture content is much greater than the threshold, 30 percent, as shown in the figure. Hence, the motor is turned off. Figure 5. Scenario 2, explains the case where the soil moisture content is lesser than the threshold, 30 percent, as shown in the figure. Hence, the motor is turned on.

Figure 5. Scenario 2.

Figure 6. Result Overview 1.
Figure 6. Result Overview 1, shows fields, soil moisture and motor state. Notice that, the motor is on i.e., ‘1’, as the soil moisture content is less than the threshold, 30 percent. The PIR sensor picks up a motion near the sensor. Hence, the value, ‘1’. As shown in the figure 7. Result Overview 2, shows three fields, temperature, humidity and cloudiness percent. These values are taken from OpenWeather by the Node MCU and updated to the ThingSpeak Server.

Figure 7. Result Overview 2.

Figure 8, depicts the visuals from the mobile application which shows different weather parameters and moisture content of the soil. The user also able to see the motor state, which is automatically controlled based on the external weather conditions and present soil moisture values.

Figure 8. The graphs obtained in ThingView mobile application.

5. Conclusion

The deployment of WSN in the farm by comprising the climatic conditions leads to having a disparity in the production and maintenance of the crops. In this paper, we have presented how irrigation and security in farming can be automated using IoT with cloud integration unlike other implementations where they have used a localized server. We formed a WSN with gateway and sensor node circuits and established a communication within the WSN, preferably in a clusterlike fashion thereby increasing the range of operation when compared to other implementations, uploaded the data into the cloud using a global gateway node, thereby increasing the ease of access to a larger extent. The soil moisture content along with weather data in the farm with periodic updates can be easily visualized on the mobile phone where we ensure that the user can remotely monitor the farm moisture content and security to be maintained automatically and remotely using WSN of soil moisture and PIR sensors.

Energy consumption at each sensor node is considered to determine the battery lifetime of WSN, sleep time of the sensor nodes have a greater impact on the energy saved so, a system with optimal sleep
time can be designed. Our work can be used to make scientific observations effectively, it helps to precisely measure and store the parameters of precision agriculture experiments. To conquer the challenges in agriculture, new applications are envisioned such as yield prediction and disease monitoring using drones (aerial and ground-based), computer vision and sensor-cloud technology. It can further be modified to design a sensor-cloud-operated environment control system for off-season production of vegetables and flowers in greenhouse farming.

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