



WIRELESS NODE BASED AUTOMATIC IRRIGATION CONTROL SYSTEM

Sandilya Kalidas, Shubham Bharadwaj, Vidhyapathi. C. M and Karthikeyan. B

Vellore Institute of Technology, Vellore, Tamil Nadu, India

E-Mail: vidhyapathi.cm@vit.ac.in

ABSTRACT

In this paper we address the issue of lack of a versatile irrigation control system, and discuss the design and implementation of a wireless nodal irrigation system which works on the basis of soil moisture levels. The said system monitors the soil moisture at fixed nodes and relays the information of moisture content to the control node wirelessly and irrigates the nodes which have a deficit of water. The sensors can be configured to work with various sensitivities and for different levels of water. The aim is to develop a cost effective and easy to use system which can be set up and used quite comfortably with any existing type of irrigation system with minimal modifications. And that, the implementation of an automated irrigation system such as this saves a lot of time for a typical farmer, which could be invested into other avenues such as increasing the yield and pest control.

Keywords: automatic, irrigation, wireless, zigbee, MSP430, low power, control system, sensor, node.

1. INTRODUCTION

The sensor system works on the basis of variation of soil resistance based on the percentage of moisture present in the soil. It is observed that when soil is dry, there is no medium for current to pass through the soil, it offers a very high resistance (in the order of a few mega ohms) when a voltage is applied to the end of it. Also when water is introduced into the soil the current has a pathway to travel and thereby the soil offers a lesser amount of resistance. The concept here is to compare the potential drop of the soil to a static voltage and decide if the soil is wet or dry. The percentage of moisture needed in the soil before it is considered to be wet is decided by the use of a potentiometer and this value can be preset or adjusted according to the needs of the farmer [1]. This sensor is placed at regular distance separations in the field, and the data from each and every sensor is sent to a control node which then analyses the data and sends water to only the nodes that are dry or not relatively wet [2].

2. DESCRIPTION

The following are the main points addressed by the Irrigation Control System.

- To minimize the manual intervention needed to irrigate a farm [3].
- To develop and implement a low cost and reliable sensor system which can monitor soil moisture.
- To create a wireless system of nodes which can send and receive data from a control node [4].
- To use a control node to turn valves on and off to send water to nodes with water deficit.

So, we have developed a system with the capacity to address all the points and simplify the chore of irrigating large farmlands.

3. IMPLEMENTATION

A. Soil moisture sensor

We use the concept of variation of soil resistance based on the percentage of moisture present in the soil. Simple logic dictates that wet things conduct electricity easier than dry things; this is due to the electrolytic properties of water. In order to use this to develop a soil moisture sensor we first need to understand how the resistance of soil varies based on the amount of water present in it [5].

Dry soil typically offers resistances in the order of a few mega ohms, and as the moisture content in the soil increases the resistance decreases and finally it drops down to a few tens or a few hundred kilo ohms. For the sake of convenience we can say that the resistance offered by soil is inversely proportional to the amount of moisture present in it.

The next question arises that how do we use this concept of soil moisture to design a sensor which can tell if the soil is wet or dry. For this purpose we use an op amp which works as a comparator. To understand how the sensor works we need to understand how a comparator works.

The comparator has two pins one negative and other positive; it compares the voltage of both pins and gives an output that is either VCC or zero. When, the output is VCC or when it is zero is defined by the following equations.

$$V < V+ \Rightarrow \text{VCC or logic 1}$$

$$V > V+ \Rightarrow 0 \text{ or logic 0}$$

Now the pins V+ and V- are to be connected to the reference voltage of 4.5V and to the soil respectively. But just comparing the voltage drop offered by the soil is not enough. So we connect a potentiometer in parallel to the probes in the soil so that the total potential drop is divided across the potentiometer and the soil. This enables us to set the sensitivity of the sensor.



Consider the case where the soil is wet. The soil offers minimal resistance hence most of the potential drop occurs across the potentiometer. This implies the voltage at V- pin will be VCC minus a very small value, i.e. a value which is larger than the reference voltage of 4.5V hence the output of the op amp is 0V or logic 0.

Now consider the case where the soil is dry, the soil offers a huge resistance which is magnitudes above the resistance offered by the potentiometer. So the potential at the V- pin will be the VCC minus a very large voltage value, i.e. a value which is less than the reference voltage of 4.5V, hence the output of the op amp is VCC or logic 1.

The amount of moisture at which the sensor detects that the soil is wet, can be changed by changing the resistance value in the potentiometer. Since the soil offers resistance less than 100Kohms when wet we use a 100K ohm potentiometer, and set the value of the potentiometer to offer resistance less than the soil. Then the voltage at V- terminal will be large enough to be more than the reference voltage and thus the sensor treats the soil as if it is dry.

The sensor itself cannot transmit data to the control node since the op amp used cannot transmit any data. Hence we use a microcontroller to transmit the raw data from the sensor [6].

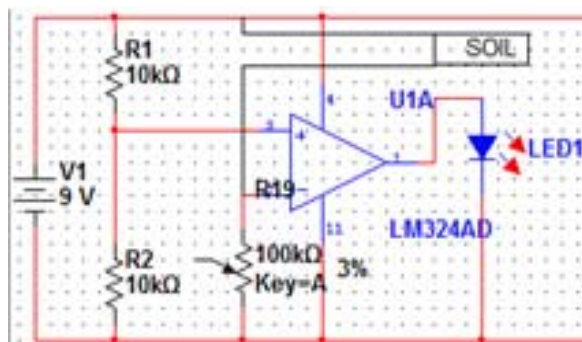


Figure-1. Sensor circuit diagram.

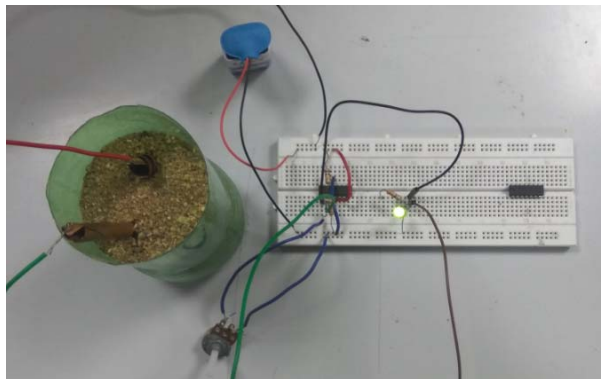


Figure-2. Sensor circuit.

B. Nodal microcontroller

The data from the sensor circuit is in the form of analog voltage and cannot be used for communication

using a UART protocol. Hence we need a low cost, low power microcontroller to handle the analog to digital conversion to transmit the data through the network.

MSP430 is a series of microcontroller which fit the needs of this system perfectly. They have multiple low power modes and can run on a battery for months on end thereby reducing the times the battery has to be replaced, they also support C programming language which is relatively simple to program and has many inbuilt libraries for ready use. They also have various serial communication peripherals inbuilt for ease of communication with other devices, all these features make MSP430 family the perfect microcontroller for the irrigation control system [7].

We have used the microcontroller MSP430G2553 as the nodal microcontroller. The job of the nodal microcontroller is to stay in a low power mode until the control node pings it for data. It then comes out of the low power mode and gets the moisture data from the sensor. The data is then converted into a string and sent to the control node.

Every node has an id, when the control node broadcasts the id of the node it wants information from all the nodes come out of the low power mode and check if the id matches its own, if it matches then it asks the inbuilt Analog to Digital Converter (ADC) to convert the output of the sensor into a digital value. The output high of the sensor is about 2V, so if the value returned by the ADC conversion is greater than 1V it concludes that the soil is dry and stores the soil condition in a character [8].

It then transmits the character to the control node and goes back into low power mode until the next time the control node pings it.

The microcontroller sends the data serially at a baud rate of 9600 to the control node, and since the data on its own does not make any sense to the other microcontrollers, it has to use some sort of protocol to send the data, since the system has to be kept simple enough to enable easy troubleshooting we have decided to use Universal Asynchronous Receiver/Transmitter (UART) to transmit the data in the nodal network. UART protocol converts the bytes it receives from the microcontroller into a single serial bit stream for outbound transmission and converts the serial bits into bytes that the microcontroller can understand. This is a very simple and easy to use piece of hardware that enables two microcontrollers to communicate with each other. It also enables microcontrollers that are from different manufacturers to communicate with each other [9].



Figure-3. Nodal microcontroller with sensor circuit.

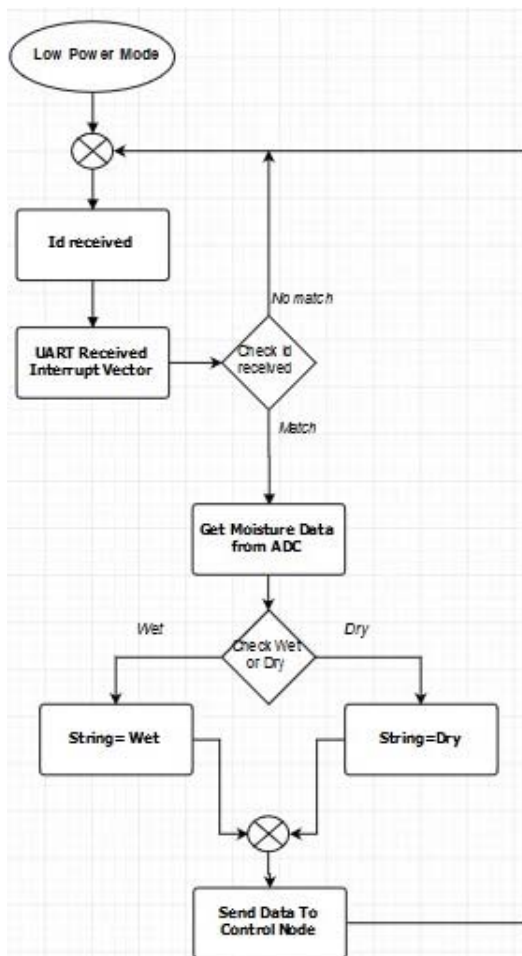


Figure-4. Nodal flow diagram.

C. Zigbee nodal network

The data in the control system has to be transmitted from the control node to all the nodes; this can be done in one of two ways: using wires, or wireless. Using wires to transmit data is good enough for testing purposes because the environment in the laboratory is controlled. But in the field where reliability is of utmost

importance we cannot use wires which pose a lot of problems and are generally difficult to handle.

So, we have to go wireless. But there are so many wireless protocols and technology available in the market right now that is difficult to choose the right one for the system. So we need to see what the specifications are that we need from the proposed wireless system.

- Simple to use
- Easily available
- Low cost
- Low power
- Good range
- Easy to set up
- Should work with existing hardware

The ZigBee (IEEE 802.15.4) protocol satisfies the most of these specifications. It is low power, with an affordable price tag and very easy to set up and use. Some ZigBee networks have shown to have range of 5-600 meters in certain conditions. They are also relatively small pieces of hardware and support transmission by UART protocol [10].

Hence we have decided to use XBEE S2 ZigBee transceivers in our system. They come with preloaded firmware and they firmware can be updated according to how you want the device to function.

Every XBEE transceiver can act as one of 3 devices, a coordinator, a router or an end device. The XBEE work using Personal Area Networks (PAN), a PAN network is like a WIFI hotspot where various devices can join the network provided they have the right credentials and use the network to transmit and receive data. In every ZigBee network, the network has to be created and maintained by a node, in XBEE that job is done by the coordinator, the coordinator can create PANs and allow devices to join them. It can also send and route data and wake up other devices in the PAN.

The router node cannot create PANs but it can join existing PANs created by the coordinator if it has the same PAN id. The router can also send and receive data, it can also route data from other nodes in the network.

The end devices are nodes which can neither create PAN nor route information from other nodes. They can only join existing PANs and send information. End devices can be put into sleep mode to save data.

In our control system the data communication is only required between the control node and the sensor nodes. The sensor nodes do not need to communicate with each other. So the control node needs to be in a position to talk to each and every sensor node and each sensor node needs to be in a position to talk only to the control node. This implies that the control node is to broadcast information in the network and call the sensor nodes are to unicast information to the control node.

So, in the control system we configure one XBEE device to be the coordinator and the put the destination as



FFFF H or put the coordinator in broadcast mode. The coordinator is then attached to the UART pins of the control node so that whatever data the control node generates the data gets flooded to all the sensor nodes.

The sensor nodes can now be either configured as routers or end devices. To decide which sensor is a router and which sensor is an end device. We follow the rule that all the sensors that are farthest from the control node they will be assigned as end devices and all the intermediate sensor nodes are configured as routers to route the information from the end devices to the coordinator. But irrespective of the fact that the node is a router or an end device the destination address of the sensor node will be assigned as 0000 H since only then will it be configured to be in the unicast mode, i.e. any data that is generated by the sensor node will get routed to the coordinator (control node). All the configuration of the ZigBee network is done by using the XCTU software [11].

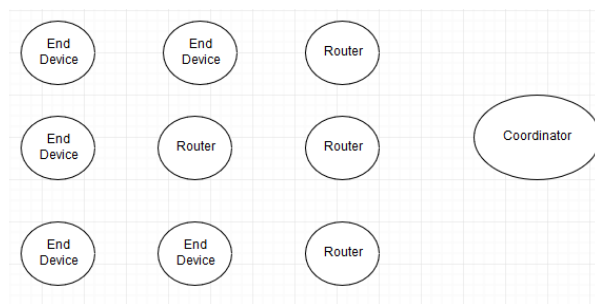


Figure-5. Wireless nodal network.

D. Control node

The most important and robust device of the irrigation control system is the control node. The control node handles the job of polling all the nodes for moisture data and it also does the job of interpreting the data and sending control signals to turn on valves to send water to nodes which are dry. In order to handle the computing requirements of the system we need a microcontroller which is more powerful, and can perform complex tasks with minimal effort. Keeping the above arguments in mind we used Raspberry PI 3 as the control node, even though it is slightly on the expensive side, it can be programmed easily and it comes with an inbuilt python based operating system which makes the job easy [12].

Here we have programmed our Pi to work in a very specific way, since the supply of electricity to farm lands is very erratic we cannot assume that the Pi will be always turned on. So we connect the Pi to the farm power supply and as soon as it turns itself on after the power to the farm is given it will run the control system code on boot.

The Pi is programmed to poll each sensor node and wait for the node to reply, whenever the node does not reply in a particular amount of time, it generates an error code saying that the particular node is at fault and to verify the power supply to the node. After it has collected the information from each and every node it will then compile all the data into a time stamped text file and stores it in its

internal memory. It this finds out which nodes are dry and then sends control signals to its General Purpose Input Output (GPIO) pins which are connected to solenoid valves. In our demonstration we have modelled the valves to be dc motors, since the circuit modelling would be same for the valves. After sending the control signals it will wait for a fixed amount of time and then repeat the polling process to check if all nodes have received water or not. It will repeat the process until all nodes are wet and then turns itself off.

The information sent by nodes is stored in a designated folder with time stamp and date so that the farmer can access it to find how the system is performing [13] [14].



Figure-6. Control node.

4. RESULTS

The control system upon testing produced very reliable outputs and we could see that the data was being collected by the control node in a very short amount of time and with good accuracy. The sensor circuits were very reliable and functioning for different sensitivities at different nodes. The system was able to function properly even when multiple false positive cases were tested and the data was being compiled and stored by the control node at regular intervals. The turning of valves was also tested by using dc motors and they were found to be turned on only when the control node sent the proper signals. The wireless system was tested for range and was found to be functioning even when there was no direct line of sight communication. The sensor nodes were also found to reply with proper information when polled by the



control node and if there was any failure to communicate, the control node reported the error in the data file.

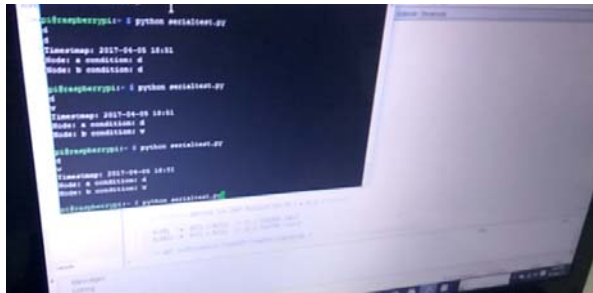


Figure-7. Data collection at control node.

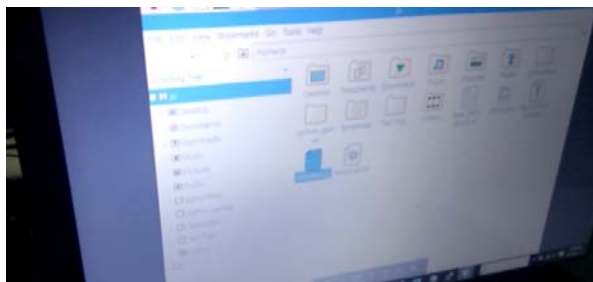


Figure-8. Data collected, stored in a .txt file.

5. FUTURE SCOPE

Currently the system only monitors and stores the data sent by each of the sensor nodes, the data from the nodes can be analyzed using neural network algorithms to find patterns of irrigation and to study the quality and frequency of irrigation. It can also be used to study the amount of water used for the irrigation of the field and the data can be correlated with rainfall patterns to predict the water requirements for the field.

The data can also be uploaded into the cloud since the Raspberry Pi supports a data connection.

6. CONCLUSIONS

On the whole we can conclude by saying that a lot of time and manpower can be saved by automating the irrigation to a large farmland, and that the manpower can be reinvested into other useful avenues by the farmer to better improve the yield. It was also found that the system could function properly even when it was tested with all the problems it would face in the field.

REFERENCES

- [1] Samy Sadeky, Ayoub Al-Hamadiy, Bernd Michaelisy, Usama Sayedz. 2004. An Acoustic Method for Soil Moisture Measurement. IEEE.
- [2] Narendra Shah and Ipsita Das. Precision Irrigation: Sensor Network Based Irrigation. https://www.researchgate.net/publication/221927923_

Precision_Irrigation_Sensor_Network_Based_Irrigation.

- [3] Purnima S.R.N. Reddy. 2012. Design of Remote Monitoring and Control System with Automatic Irrigation System using GSM-Bluetooth. International Journal of Computer Applications. 47(12): 888-975.
- [4] G. Vellidis, M. Tucker, C.Perry, C. Kevin, C.Bednarz. 2008. A realtime wireless smart sensor array for scheduled irrigation. Elsevier.
- [5] Sri Harsha Modali, K.Sandilya, V.Venkata Ramana Raju. 2016. Automatic Grid Irrigation System Based On Soil Moisture. IJSRD.
- [6] C.H. Chavan, P.V.Karande. 2014. Wireless Monitoring of Soil Moisture, Temperature and Humidity using Zigbee in Agriculture. IJEET.
- [7] John Davies. MSP 430 Microcontroller Basics. Newnes Publications.
- [8] Lande Westlund. 2006. Introduction to Msp430 Adc's. MSP430 Advanced Texhcnical Conference.
- [9] Msp430 Uart Tutorial, <https://www.embeddedrelated.com/showarticle/420.php>.
- [10] XBee/Xbee-PRO RF Modules, Product Manual, <https://www.sparkfun.com/datasheets/Wireless/Zigbee/XBee-Datasheet.pdf>.
- [11] Fabio Leccese. 2013. Remote-Control System of High Efficiency and Intelligent Street Lighting Using a ZigBee Network of Devices and Sensors. IEEE Transactions on Power and Delivery.
- [12] Brian Benchoff. Introducing the Raspberry Pi 3. <http://hackaday.com/2016/02/28/introducing-the-raspberry-pi-3/>.
- [13] Nikhil Agarwall, Smita Singhal. 2015. Smart Drip Irrigation System using Raspberry pi and Arduino. International Conference on Computing, Communication and Automation.
- [14] Suruchi Chawla, Amita Kapoor, Shallu Sharma, Bhanvi Shukla, Monica Gupta, Pragya Kaushik, Shreshtha Pushkar. 2016. App based Garden Bot for Regulation of Water Level in plants. IRJET.