A Wireless Application of Drip Irrigation Supported by Soil Moisture Sensors

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Abstract— In the past couple of decades, there is rapid growth in terms of technology in the field of agriculture. Traditional instrumentation based on discrete and wired solutions, presents many difficulties on measuring and control systems especially over the large geographical areas. An intention of this topic is to describe the design and implementation of a low-cost multi-mode control for an irrigation system. The system uses soil water potential measurements, the weather condition parameters and the set points data provided by the user to decide when and how much water to apply to the irrigated field. The designed system has 3 units namely: Base Station Unit (BSU), Valve Unit (VU) and Sensor Unit (SU), mainly focuses on predicting the start of germination of the disease. Sensor Unit is used to detect different environmental condition across the farm and the sensed data is displayed on LCD using ARM. ARM processor wirelessly transmits different environmental conditions across the farm to Base Station Unit where data is stored, and analyzed. Base Station Unit checks the present data with stored condition and if matches then it commands ARM to operate relay in the Valve Unit. Full circuit and program codes were implemented to verify system operation. This describes an application of a wireless sensor network using XBEE for low-cost wireless controlled irrigation solution and real time monitoring of water content of soil. In addition, the developed irrigation method removes the need for workmanship for flooding irrigation.

Key words: Base Station Unit, Valve Unit, Sensor Unit, XBEE Wireless Module, ARM Processor

I. INTRODUCTION

Agriculture is main source of livelihood of people. It provides food as well as large employment. So modernization of agriculture is important because traditional farming is unable to boost up the crop yield. Therefore farmer start to utilize the various technology to achieve better yield and reduce the required man power. As the source of life, water is an essential element in modern agriculture. So with sharp increase of population, the development of modern agriculture has severe problem concerning water resources [15]. Human being is facing a double challenge of both protecting and utilizing water resources. The crop yields depend on the sufficiency of water supply. Water is essential for crop production so the effect of water, rainfall and irrigation on crop growth and yield under different agro climatic conditions is essential in planning, design and operation of irrigation schemes. The maximum potential yield of crop is determined by climate and availability of water in quantity and time, including periods of water shortage during the critical periods in its growing phase. The irrigation system is to be designed and managed to meet the crops water requirement in quantity and time to attain optimum yield.

In conventional system, the farmer has followed a schedule for watering, which is different for different crops [12]. In automatic drip system, irrigation will take place only when there will be requirement of water. A variety of drip irrigation method has been used but most of them are very expensive and complicated. So proposed application system is minimal cost & useful for different crops irrigation. Too much watering causes diseases to plants and even they die out [14]. To provides uniform and required level of water for both plain and sloppy areas and avoids the water overflow at the sloppy areas and considering the current labor shortage situation, the automated sensing system will be most appropriate. The rapid changing agricultural market requires new farming strategies [8]. The pest and diseases have increased; insects are responsible for major kinds of damage to growing crops. It directs injury to the plant, which eats leaves or fruit, or roots. The real time values of soil moisture, air humidity, temperature and water level in the soil are wirelessly transmitted using wireless technology and protection from insect attack to the crop for better production.

During monsoon months it is seen that the germination rate of the disease is quite high [2]. Different environmental conditions that are responsible for the growth of gummosis are as: Temperature - 28 to 32^{0}C, Soil moisture - around 65% for 15 days, Relative humidity 80%. This environment depends on particular set of temperature, soil moisture, and relative humidity. Thus the three sensors, temperature, soil moisture, relative humidity, are used in the system. The real time values of these sensors are given to ARM. Now these values are displayed on LCD as well as wirelessly transmitted. ARM verifies the real time values with reference set of conditions. If it detects the large change in the observations, then it operates the motor.

Paper is divided into five sections. First section gives the introduction of the system. It provides the need of the system, basic theme, etc. Next section is collection of some of the previously developed system. Flow of development of system is discussed in section three. Description of all the components and their requirement is mentioned. Fourth section consists of Practical results. And the last section gives the conclusion of the system.

II. DIFFERENT MONITORING SYSTEMS IN AGRICULTURE

Field of agriculture has seen the rapid advancement in terms of technology from past couple of decades. Farmers start to utilize various monitoring and controlled system in order to increase the yield. Different agricultural parameters like temperature, relative humidity, soil moisture, carbon dioxide, light detection, soil pH, *etc*. are monitored as well as controlled. Here it is review of some of these monitoring systems which can help the farmers to improve the yield.

Hierarchical WSN was installed to measured different soil parameters. Underground placed sensors send the data to base node through various relay nodes. Base node consists of 8051 microcontroller [3]. Using the same microcontroller, a password protected water flow control system was developed using dual tone multi frequency (DTMF) technique. DTMF tones are used for the communication between farmer and monitoring station [4].

In one of the systems, Wi-Fi module is used for wireless communication. The system used Atmega controller. It mainly focuses on transmitting different environment conditions to selected server *via.* routers [5]. One other system with same controller, monitored temperature and water usage. The real time values are transmitted wirelessly to the substation using XBEE. Substation performs the controlling action on motor and irrigation valve according to preset value of moisture as set by the farmers [6].

Environment inside polyhouse was controlled using programmable interface controller (PIC). The system has set some references like T_{min}, T_{max} and Rh_{min}. Once these references are violated then controller would command to relay operating circuitry for proper controlling action [7]. An irrigation management model for higher crop yield was presented. This model is based on estimation of soil water tension (SWT). PIC would modify the irrigation scheduling based on this SWT value. Bluetooth and GSM based remote monitoring and control system is proposed using PIC. Abnormal conditions across the field are informed to farmers *via.*SMS and then farmer can take appropriate controlling action [8].

A. *Effect of Major Climatic Factors on Crop Water Needs:*

The greater need of water for crops are thus found in areas which are hot, dry, windy and sunny. The lowest values are found when it is cool, humid and cloudy with little or no wind. The water requirement of crops varies with the growth stage of the crop, ground area covered by the crop, crop height and change in leaf area. The growing period of crops can be divided into four stage.

Climatic Factor	Crop water need	
	High	Low
Temperature	hot	cool
Humidity	low (dry)	high (humid)
Wind speed	windy	little wind
Sunshine	sunny (no clouds)	cloudy (no sun)

Table 1: Water Need in Different Climatic Conditions

The relationship between different climate factors and crop water requirement is as shown below.

	Initial stage	Developm-ent stage	Mid season stage	Late season stage
Wheat	15	25	50	30
	15	30	65	40
Onion	15	25	70	40
	20	35	110	45
G.nut	25	35	45	25
	30	40	45	25
Potato	25	30	30	20
	30	35	50	30
Soybean	20	30	60	25
	20	30	70	30
Tomato	30	40	40	25
	35	45	70	30

Table 2: Approximate Duration of Growth Stages for Various Field Crops

III. SYSTEM DEVELOPMENT

The developed system (but not implemented) is used to predict the commencement of germination of gummosis. System consists of Sensing unit, LCD, wireless module and ARM processor. Sensing unit read the different atmospheric conditions. It consists of temperature sensor, relative humidity sensor and soil moisture sensor. The readings are given to ARM (LPC2138). Processor will display these reading on LCD as well as transmit it through wireless module (XBEE module). Block diagram of transmitter is as shown in Figure 1. Here, in the figure, all the sensors are interfaced to ARM.

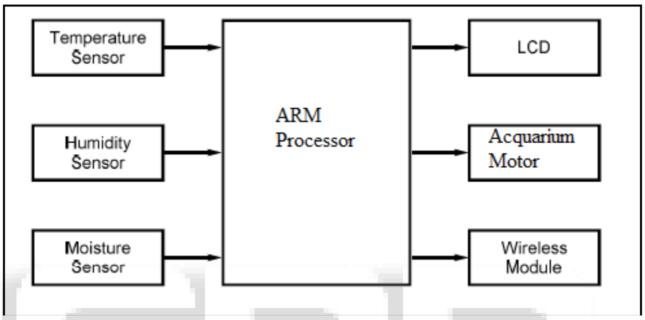


Fig. 1: Block diagram for proposed Irrigation System

Receiver consists of wireless module, serial communication device (RS 232) and personnel computer. Wireless module will receive these different sensor readings and give it to computer via RS 232. Receiver is as shown in Figure 2. Wireless module is interfaced to central unit (Laptop) using standard communication protocol RS 232.

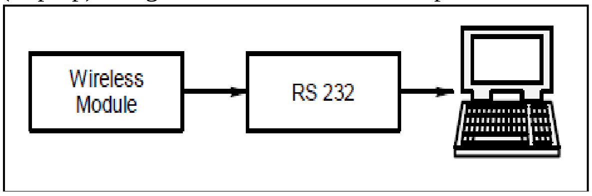


Fig. 2: Block Diagram of Receiver

A. *Soil Moisture Sensor and Unit:*

In the developed system, 10 HS coded pre-calibrated Soil Moisture Sensor of Decagon has been used to measure water content of soil (Figure 3). The 10 HS has a low power requirement and very high resolution. This gives you the ability to make as many measurements as you want (that is, hourly) over a long period of time with minimal battery usage. 10 HS needs 12 to 15 mA and runs with 3 to 15 V DC. Output voltage of sensor is 300 to 1250 mV (independent from the excitation voltage). The 10 HS measures the dielectric constant of the soil in order to find its Volumetric Water Content (VWC) using a capacitance technique. Since the dielectric constant of water is much higher than that of air or soil minerals, the dielectric constant of the soil is a sensitive measure of volumetric water content. The SU acquires data given by the ADC, and the data sent to BSU. Value of ADC input which comes from the sensor is stored in a 10-bit register. Different type of sensors can be added easily for future developments. In this design, a 20 MHz oscillator was selected to use. The output value which was produced by the sensor value is as an analog data and it is converted to digital data by the ARM and sent to PC via serial ports through XBEE module.

Fig. 3: Soil Moisture Sensor brand by Decagon

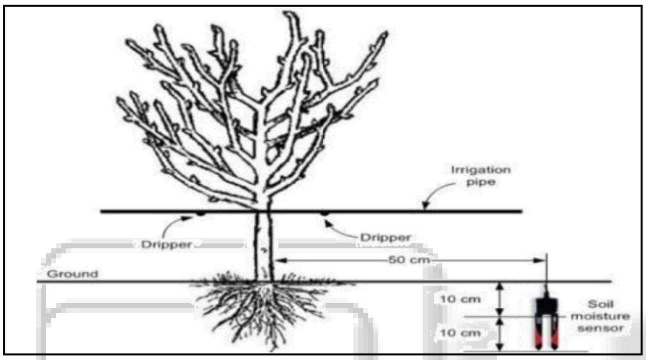


Fig. 4: Location of the Soil Moisture Sensor in This Application

B. *Humidity Sensor:*

Relative humidity is a measure, in percentage, of the vapor in the air compared to the total amount of vapor that could be held in the air at a given temperature. SY-HS-220 is used to measure humidity. It is shown in Figure.

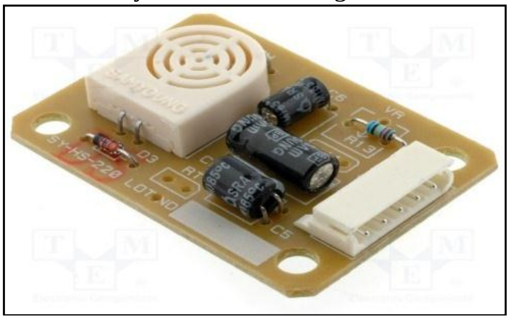


Fig. 5: SY-HS-220 Humidity Sensor

It operates on DC 5 V of supply which can be easily arranged as ARM will also be required the same voltage. Its operating temperature range is 0 - 60°C which means that it is suitable for field work. It accurately tracts the humidity range from 30 - 90% which is more regularly find out inside the cropping land.

C. *Temperature Sensor:*

National Semiconductor's LM35 IC has been used for sensing the temperature. It is shown in Figure 4. The LM35 series are precision integrated circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 is rated to operate over a -55° to +150°C temperature range. This makes it suitable for field work.[10]

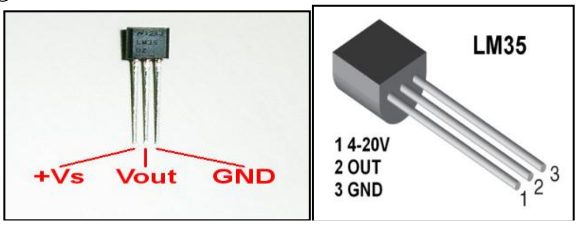


Fig. 6: LM 35 Temperature Sensors

D. *Valve Unit:*

Valve unit has the same connection with wireless module and the same properties with Sensor Unit. It has an output for controlling the valve.

E. *Base Station Unit (BSU):*

The BSU is a master device that is programmed to read and to evaluate sensors data, to control valves and to communicate with other units. The mounted PCB was interfaced to the outsides by a RS- 232 serial port.

F. *Transmitting Technology:*

Wi-Fi and Bluetooth. are high costs, hard to be developed and limited signal coverage. So the Zigbee WSN technologies are most suitable for agriculture applications when compared with Wi-Fi and Bluetooth.

XBee is a low-cost and low-power wireless technology. XBee wireless technology was first introduced with XBee alliance being formed between Philips, Motorola, Honeywell, Invensys and Mitsubishi Electric in October 2002 under IEEE 802.15.4 WPAN standard. XBee operates in the 2.4 GHz band with a data transfer rate of 250kbps and it supports peer to peer, point to point and point to multipoint networking methods with current consumption ranging between 30 to 40mA for data transmission.

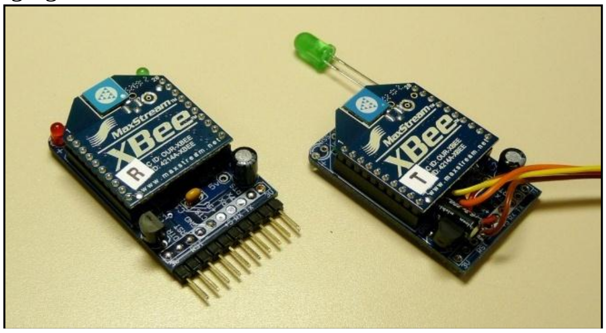


Fig. 7: XBEE Transmitter & Receiver

Mode	Bluetooth	Wi-Fi	XBee
Operating Band (kB/s)	1000-3000	11000+	20-250
Coverable Distance (m)	20(Class II) 100+(Class I)	100+	20-70
Number of	7	32	25400

nodes			
Power Consumption (mA)	42(Class II) <150(Class I) Medium	300 High	30 Very low
Memory/kB	50+	70+	40+
Technical Advantages	Cost Efficient	Bandwidth Spectrum	Low Power Consumption & Cost
Operating Range (m)	10	50-100	10-100 100(Indoor) 1500(Outdoor)
Network Protocol	Ad-hoc	Point to hub	Ad-hoc, peer to peer
Monitoring Station	PC	PC, Mobile	PC

Table 1:

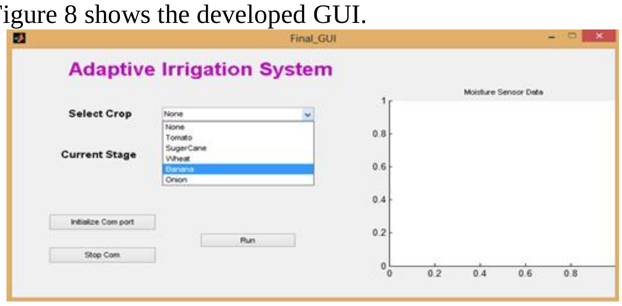
The current widely used technologies of Bluetooth and Wi-Fi are compared with the XBEE technology and the advantages of XBEE over Bluetooth and Wi-Fi are numerous for our application as seen from Table 3. XBEE works over a larger distance then the Bluetooth and with lower power requirements then the Wi-Fi tech. This allows for a mesh network to be created which can cover more area and can also remain active for 6months-2 years on two AA batteries .The XBEE has better latency and takes 15ms to wake up from sleeping mode as compared to the Bluetooth which requires 3-4 seconds. With this small wake-up time it is possible for the node to sleep until critical data needs to be sent at which point it can wake-up, synchronize itself with the host node, transmit and go back to sleep.

G. ARM7 Processor (LPC 2138):

The LPC2131/32/34/36/38 microcontrollers are based on a 16/32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combine the microcontroller with 32 kB, 64 kB, 128 kB, 256 kB and 512 kB of embedded high-speed flash memory. A 128-bit wide memory interface and an unique accelerator architecture enable 32-bit code execution at maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30 % with minimal performance penalty.

IV. EXPERIMENTATION

ARM is programmed with the Embedded C. A GUI is developed using MATLAB to run on the PC. The developed GUI serves as a communication link between the wireless sensor and the computer at the base station. The developed software records moisture in a backend database. In addition, it helps in visualize moisture data by displaying it. Figure 8 shows the developed GUI.



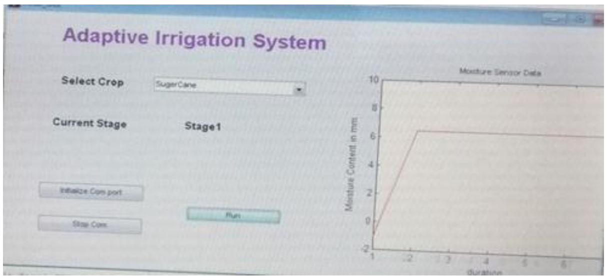


Fig. 8: Window Faced By User after Running Execution GUI.M File in MATLAB

Fig. 9: Practical Setup

V. CONCLUSION

The developed system is Simple and cost effective than most other systems present in the market. It measures different environmental conditions. It includes measurement of atmospheric temperature, relative humidity and soil temperature, *etc*. System uses wireless module for the data transfer, communication purpose. So it can be use in open fields as well as inside greenhouse as the range of wireless module is up to 25m with / without different obstacles like trees, benches, walls, cupboard, magnet, *etc*. With the use of wireless module, system becomes flexible, robust, *etc*. Sensors can be placed anywhere in the field and if there is need of relocation then it can be easily done. System is also tested for different temperature and it is found that all the sensors work with minimum deviation in output. With the use of drip irrigation, water is provided directly to the roots of the crop. Thus wastage of water is minimized and water resources are optimized to obtain better crop yield. This system is advantageous to farmers as it not only saves water but also helps farmers in fighting the diseases. Thus it will increase the yield of the crop.

VI. ACKNOWLEDGEMENT

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