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Remote Monitoring of Agricultural Land Using Wireless Sensor Nodes

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Abstract: *The aim of the project is to design a microcontroller based embedded system for environmental monitoring and control of agriculture fields and transmitting the sensor signals to be shared in the Internet Cloud. The system consists of two sensor nodes designed with LPC2148 microcontrollers. One node consists of temperature and humidity sensors whereas other node consists of gas and soil moisture sensors. The sensed values are sent to the Raspberry Pi microcontroller via ZigBee protocol and also displayed on the webpage. Raspberry Pi acts as a main server. When the soil moisture value is sensed below the threshold, the motor is turned on in order to supply water to the field and humidity sensor is used to identify humidity of the soil and if it is less than the threshold, another motor is turned on .The motors are turned on remotely by using a user friendly Graphical User Interface (GUI) buttons in the web page. Experimental results taken for different dates and different times indicate that the system is highly reliable.*

Keyword: *Environmental Monitoring; LPC2148; Raspberry Pi; webpage; ZigBee;*

1. INTRODUCTION

Precision irrigation involves the accurate and precise application of water to meet the specific requirements of individual plants or crops and minimize adverse environmental impact. It is also estimated that 40% of the water used for agriculture in developing countries is lost, either by evaporation, spills, or absorption by the deeper layers of the soil, beyond the reach of plants' roots (Yassine Jiber et al, 2011). Wireless Sensor Network (WSN) is the ideal candidate to provide effective and economically viable solutions for a large variety of applications ranging from health monitoring, agriculture, environmental monitoring to military operations. The agricultural scenario seems to be one of the most promising application areas for Wireless Sensor Network due to the necessity of providing the agricultural production chain in terms of precision and quality.

This project implements ZigBee based wireless sensor network in agriculture such as monitoring of environmental conditions like pH, soil moisture content, soil temperature and humidity. The aim of this project is to monitor and maintain the farm from any part of the world through internet. The real status of his farm can be observed by the owner and by logging into the webpage can also control his farm. The cloud based user friendly interface facilitates real-time data logging of environmental parameters. Sustainable agriculture promises economic stability for farmers to lead a better quality of life. Also helps in proper utilization of the available resources and helps in avoiding wastage of electricity and water. Provides a user-friendly interface hence will have a greater acceptance by the technologically unskilled workers.

Advancements in sensor technology and control systems allow for optimal use of resources. The proposed system will lessen labor, conserve water, increase crop yield, provide maximum automation and benefit the society by adopting the fast growing Internet of Things to implement newer and sustainable ways of farming. Raspberry Pi is a low cost ARM powered Linux based computer which acts as a server, and it communicates with clients with LAN or external Wi-Fi module. It also features a monitoring system that allows the owner to control the field parameters remotely even from a smart phone; over the internet through the webpage.

The Section 2 deals with the related works of the agricultural land monitoring system. The section 3 gives the highlights of the proposed system. The Section 4 deals with the pseudo code required for the system. The Section 5 shows the experimental results obtained from the agricultural land monitoring system. The Section 6 deals with the overall conclusion

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of the paper. The Section 7 gives the way the proposed system could be enhanced in its future work.

2. RELATED WORKS

Rebala Neelakanteshwar Reddy et al (2016) proposed cost effective method of irrigation. The soil's fertility degradation is also checked using a connected network by monitoring the fertility content of the soil using ion selective electrodes. The system implements a ARM Cortex processor and GSM module. The major drawback is that the farmer can only monitor the farm remotely. There is no two way control of the proposed system.

Dragoş Mihai Ofrim et al (2010) have proposed a system for temperature and humidity monitoring of the environment using sensors and Zigbee network. Parameters that have been taken into consideration are resolution, accuracy, acquisition rate, energy consumption, flexibility etc. The designed system allows multi-point monitoring at any location, without any need of wired connection and has intelligent sensors. The measuring point density offers high accurate data even from the remote locations. A split is created, in terms of physical connection, between the measuring, monitoring and control parts, making the system extremely flexible. The disadvantage of this system is that the power consumption was on the higher end and hence efficient management of resources at sensor nodes was required.

Vijula Grace et al (2015) proposed wireless sensor based control system in agriculture field. Soil moisture sensor is used to sense the moisture level of the soil without man power. This is done by receiving a message from the user. There is a sensor unit i.e. a soil moisture sensor, which helps to identify the moisture level of the soil by inserting it into the soil. The moisture content is sensed and it is given to the ARM controller which controls the entire system. The ARM controller gives a pulse to the GSM module for sending and receiving the information. There is a motor pump which is controlled by the wireless controller. From the GSM module provided in the field, user gets an alert when the moisture sensor output is less than that of the threshold moisture level. Once they receive the message, user sends 'ON' message to the GSM module and it gives an alert to the user as 'Pump ON'. The major drawback of the system is duration of the back-up battery power supply is less.

Balamurali and Kathiravan (2015) proposed a system for monitoring temperature, humidity, soil PH of agricultural lands. Various routing protocols like AOMDV (Ad-hoc On demand Multipath Distance Vector Routing), AODV (Ad-hoc On demand Distance Vector Routing), DSR (Dynamic Source Routing) and Integrated MAC and Routing protocol (IMR) for precision agriculture using WSN are analyzed. This analysis draws conclusions that Integrated MAC and Routing Algorithm is best suitable for multi-hop routing for precision agriculture using Wireless Sensor Network (WSN) in-terms of Network life time. The network lifetime is considered as the time at which the first node in the WSN dies. The drawback is that throughput and end-end delay was not analyzed.

3. PROPOSED SYSTEM

Figures 1, 2 and 3 show the block diagram of the agricultural land monitoring system. There are three elements in the system that must be set and maintained, namely temperature, humidity, gas and soil moisture.

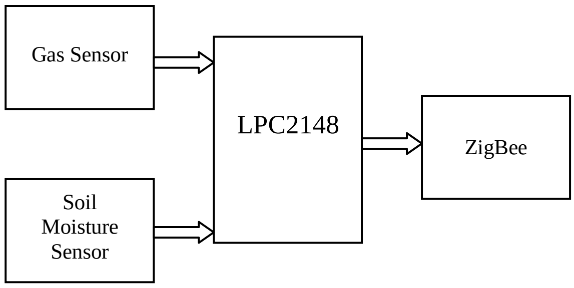

Figure 1 NODE 1 Block diagram

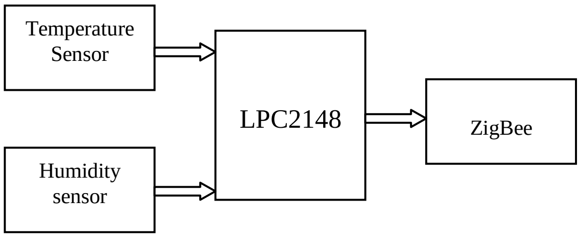

Figure 2 NODE 2 Block diagram

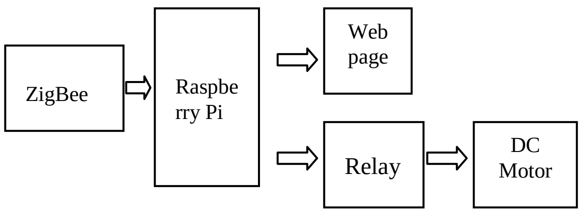

Figure 3 Receiver Side Block diagram

Each node has LPC2148 microcontroller, sensors and ZigBee module. In Node 1, gas and soil moisture sensors are interfaced to LPC2148 microcontroller and in Node 2, temperature and humidity sensors are interfaced to LPC2148 microcontroller. These sensors sense the values accordingly (Balamurali and Kathiravan, 2015). The ZigBee protocol is used for transmitting the sensor values wirelessly to the Raspberry Pi which is the main server. The Raspberry Pi receives the sensor values and updates it to the webpage (Sreekantha and Kavya, A. M, 2017). From the webpage, the sensor values could be monitored remotely. When the humidity value is less than the threshold or when the soil moisture value is below the threshold level, the motor is activated by remote control from the webpage (Guneet Mander and Mohit Arora, 2014).

The schematic of the prototype is shown in Figure 4 and Figure 5. The implementation of proposed system enables easy monitoring of agricultural land by farmers. Also the webpage is utilized for controlling the motor remotely.

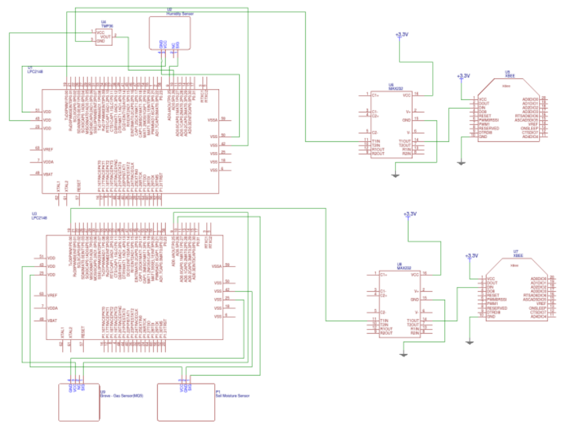

Figure 4 Schematic diagram of Transmitter Side

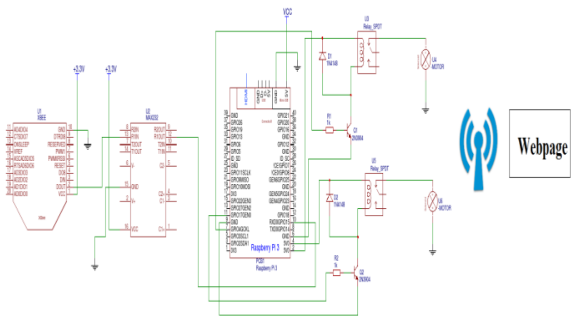

Figure 5 Schematic diagram of Receiver Side

The proposed system has two separate nodes with two ARM microcontrollers. In Node 1, it has a humidity sensor whose data pin is connected to pin 9 (AD0), Vcc to pin 23, Gnd to pin 18 and a temperature sensor whose data pin is connected to pin 10 (AD0), Vcc to pin 43, Gnd to pin 25. In Node 2, it has a soil moisture sensor whose data pin is connected to pin 10 (AD0), Vcc to pin 43, Gnd to pin 18 and a gas sensor whose data pin is connected to pin 9 (AD0), Vcc to pin 23, Gnd to pin 6.

Pin 19 (TxD) of ARM controller is connected to pin 11 (T1IN) of MAX232. Pin 14 (T1OUT) of MAX232 is connected to pin 3 (DIN) of Zigbee which acts as a transmitter. Pin 2 (DOUT) of Zigbee which acts as a receiver is connected to pin 13 (R1IN) of MAX232. Pin 12 (R1OUT) of MAX232 is connected pin 10 (RxD/GPIO15) of the Raspberry Pi. The relay is connected between the positive rail and the collector of the transistor. When the input signal passes through the 1 K resistor to the base of the transistor, it conducts and pulls the relay.

By adding a 470uF electrolytic capacitor at the base of the relay driver transistor, a short lag can be induced so that the transistor switches on only if the input signal is persisting. Again, even if the input signal ceases, the transistor remains conducting till the capacitor discharges completely. This avoids relay clicking and offers clean switching of the relay. IN 4007 diode eliminates back emf when the relay switches off and protects the transistor.

4. PSEUDO CODE

For developing the agricultural land monitoring system, Python, a high level script language is used on the underlying Raspbian OS. Controlling the DC motor using a webpage has been implemented. The pseudocode for reading the sensor values from the LPC2148 microcontrollers and displaying it on the Raspberry Pi terminal and a PHP code for displaying on the webpage are given below.

4.1 ARM Code for Reading Sensor Values

The Figure 6 is the pseudocode to read the temperature, humidity, soil moisture and gas sensor values and display it on the terminal. The pseudocode includes reading and writing characters from/to Serial Port. The ADC channels are enabled and interrupt signals is also enabled. The Analog sensor values are converted into digital. Finally, the sensor values are displayed on the terminal.

```
include header files
include library files
define variables
Write character to Serial Port,
int putchar (int ch)
{
 if (ch == '\n')
{
while (!(U0LSR & 0x20));
   U0THR = CR;
}
 while (!(U0LSR & 0x20));
 return (U0THR = ch);
}

Read character from Serial Port,
int getchar (void)
{
 while (!(U0LSR & 0x01));
```

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```
 return (U0RBR);
}

Write character to Serial Port,
int putchar1 (int ch1)
{
 if (ch1 == '\n')
 {
  while (!(U1LSR & 0x20));
  U1THR = CR;
 }
 while (!(U1LSR & 0x20));
 return (U1THR = ch1);
}

Read character from Serial Port,
int getchar1 (void)
{
 while (!(U1LSR & 0x01));
 return (U1RBR);
}

Initialize arrays for the sensors
Enable RXD0 and TXD0
Enable ADC0.1
Enable ADC0.2
Enable ADC0.3
Set the cclk to 30 Mhz
ADC configuration bits CLK = 9clks/8Bit |
BURST=1 | CLKDIV = 0x06
Start ADC now
Serial port initialization
VIC slot enabled
Pass address of UART0
Enable UART0 Interrupt
Configure P0.16 Output
Initialize Interrupt 1
Read A/D Data Register
Wait for the conversion to complete
Prints temperature values
{
T = (AD0DR1 >> 6) & 0x03FF;
delay(5);
T_F = T;
sprintf (Temp, "%4.2f", (T_F));
}
Prints Humidity values
{
H = (AD0DR2 >> 6) & 0x03FF;
delay(5);
U0THR =H;
sprintf (H, "%d", H);
}
Prints soil moisture values
{
P = (AD0DR3 >> 6) & 0x03FF;
delay(5);
U0THR = P;
H_F = P;
sprintf (P, "%4.2f", (H_F/4));
}
Prints gas values
{
if(H > 20)
{
   U0THR = G;
   delay(100);
   sprintf (G, "%d", G);
}
}
```

Figure 6 ARM code for reading Sensor values

4.1.1 Displaying Sensor Values on Raspberry Pi from ARM Microcontroller

The Figure 7 is the pseudocode for displaying the Sensor values on the Raspberry Pi terminal. Request and acknowledge signals are utilized for receiving the Sensor values from ARM Microcontroller via Zigbee. Also the GPIO pins for DC motor is set.

```
import libraries
Set the GPIO mode to BCM
Set the baudrate to 9600
Initialize variables as rcv and data
Set the request and acknowledge pins
Assign the GPIO pins for the motors
while True:
   for v in pin:
         if GPIO.input(v) is 1:
            print v,'on'
         else:
            print v,'off'
Reading the Sensor values,
for i in range (0,len(ack)):
       while (rcv is not ack[i]):
         port.write(req[i])
         rcv = port.read(1)
       for k in range(0,4):
         rcv = port.read(1)
         data+=rcv
   if (len(data)<4):
         data=''
       else:
       f.write(ack[i]+data)
       f.close()
       print ack[i]+data
```

Figure 7 Displaying Sensor values on Raspberry Pi from ARM Microcontroller

4.1.1.1 PHP Code

The Figure 8 is the pseudocode for controlling the DC Motor from a webpage. The variable is checked if it is set and accordingly displays the Motor condition.

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The sensor files are checked in the pi home directory and opens if it is found.

The motors are set to GPIO pins 4 and 17

```
$setmode4 = shell_exec("/usr/local/bin/gpio -g mode
4 out")
$setmode17 = shell_exec("/usr/local/bin/gpio -g mode
17 out")
Checks if the variable is set
{
   if(isset($_GET['m1on']))
   {
      Executes command via shell and displays
      "MOTOR1 is on"
   }
   else if(isset($_GET['m1off']))
   {
      Executes command via shell and displays
      "MOTOR1 is off"
   }
   if(isset($_GET['m2on']))
   {
      Executes command via shell and displays
      "MOTOR2 is on"
   }
   else if(isset($_GET['m2off']))
   {
      Executes command via shell and displays
      "MOTOR2 is off"
   }
Checks for the file in the pi home directory
{
   if file is present
   {
      File is opened
   }
   else
{
      Displays unable to open file
   }
Check for all the sensor files in the pi home directory
```

Figure 8 PHP Code

5. EXPERIMENTAL RESULTS

Updating the temperature, humidity, gas and soil moisture values which have been sensed in the field onto the webpage is shown below.

The Figure 9 shows the agricultural land monitoring system. There are three sections in the project. First section deals with the ARM Microcontroller, sensors and ZigBee.

In Node1, the soil moisture and gas sensors are interfaced with LPC2148 microcontroller. In Node2, the temperature and humidity sensors are interfaced with another LPC2148 microcontroller. There are two ZigBee transmitters kept in each node. The Raspberry Pi acts as the main server. The ZigBee receiver is connected with the Raspberry Pi. It receives the sensed values from the sensors interfaced at two nodes and displays it on the Raspberry Pi terminal.

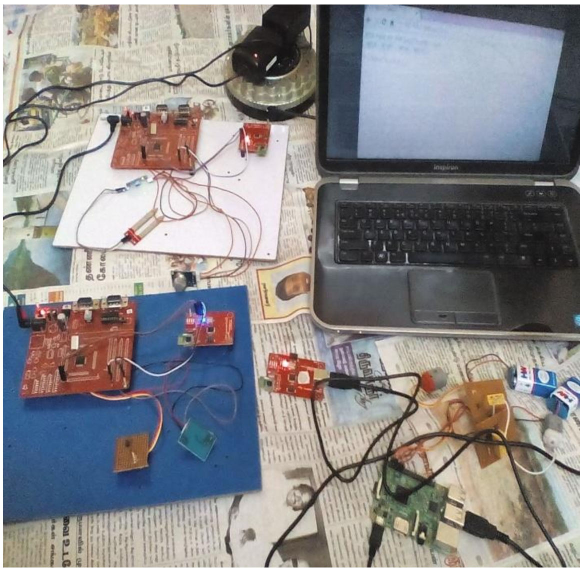

Figure 9 Agricultural land Monitoring System

TABLE I SENSOR VALUES AT DIFFERENT TIMES AND DIFFERENT DAYS

Date and Time	**Temp (°F)**	**Output Voltage (V)**	**Hum idity**	**Output Voltage (V)**
11-4-17 08:00 am	100	0.32	54	0.38
11-4-17 05:30 pm	104	0.34	32	0.12
12-4-17 06:30 am	86	0.29	390	1.29
12-4-17 11:30 am	130	0.39	38	0.22
13-4-17 08:30 am	106	0.35	52	0.33
14-4-17 09:30 am	106	0.35	48	0.28
14-4-17 12:00 pm	128	0.36	12	0.09
15-4-17 01:00 pm	128	0.38	10	0.07
17-4-17 10:00 am	110	0.36	46	0.13
21-5-17 12:30 pm	132	0.40	08	0.06
22-5-17 04:00 pm	120	0.37	28	0.11

To the Raspberry Pi, two DC motors are interfaced which would be driven by a relay. The power supply for the DC motor is 9V battery. The relay is connected between the positive rail and the collector of the transistor. When the input signal passes through

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the 1 K resistor to the base of the transistor, it conducts and pulls the relay. IN 4007 diode eliminates back emf when the relay switches off and protects the transistor. The webpage is utilized in controlling the DC motor remotely according to the sensor value variation (Sathish kannan and Thilagavathi, 2013).

TABLE 2 SENSOR VALUES AT DIFFERENT TIMES AND DIFFERENT DAYS

Date and Time	Gas	Output Voltage (V)	Soil Moisture	Output Voltage (V)
11-4-17 08:00 am	250	0.80	304	1.92
11-4-17 05:30 pm	276	0.98	18	3.16
12-4-17 06:30 am	290	0.99	530	1.22
12-4-17 11:30 am	392	1.14	380	1.82
13-4-17 08:30 am	336	1.03	472	1.34
14-4-17 09:30 am	412	1.17	376	1.88
14-4-17 12:00 pm	330	1.02	442	1.54
15-4-17 01:00 pm	344	1.04	20	3.15
17-4-17 10:00 am	526	1.54	590	1.23
21-5-17 12:30 pm	310	1.01	260	2.24
22-5-17 04:00 pm	250	0.82	52	2.98

The Temperature, Humidity, Soil Moisture and gas sensor values and its output voltages are noted down in Table I and Table 2 at different times and different days.

On April 11 (8:00 am), the node 1 containing soil moisture sensor sense 304 which is up to the optimum level hence the Motor1 is not turned on. Similarly the node 2 containing humidity sensor sense 54 which is also above the optimum level hence the Motor2 is also not turned on as shown in Figures 10 (a) and 10 (b)

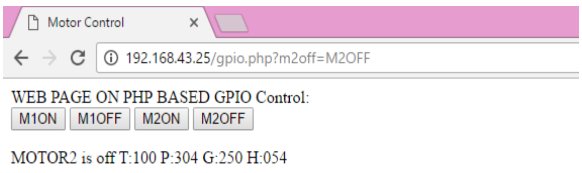

Figure 10 (a) Sensor values and Motor2 OFF at 8 am on April 11

Figure 10 (b) Sensor values and Motor1 OFF at 8 am on April 11

Figure 11 (a) Sensor values and Motor1 ON at 5:30 pm on April 11

On April 11 (5:30 pm), the node 1 containing soil moisture sensor sense 18 which is below the optimum level hence the Motor1 is turned on in order to supply water to the field. Similarly the node 2 containing humidity sensor sense 32 which is also above the optimum level hence the Motor2 is also not turned on as shown in Figures 11 (a) and 11 (b).

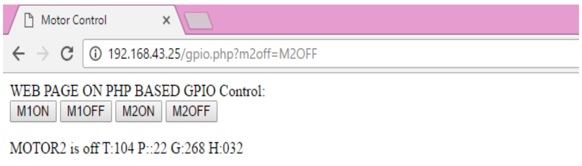

Figure 11 (b) Sensor values and Motor2 OFF at 5:30 pm on April 11

On April 12 (6:30 am), the node 1 containing soil moisture sensor sense 530 which is up to the optimum level hence the Motor1 is not turned on. Similarly the node 2 containing humidity sensor sense 390 which is also above the optimum level hence the Motor2 is also not turned on as shown in Figures 12 (a) and 12 (b)

Figure 12 (a) Sensor values and Motor2 OFF at 6:30 am on April 12

Figure 12 (b) Sensor values and Motor1 OFF at 6:30 am on April 12.

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Figure 13 (a) Sensor values and Motor1 OFF at 11:30 am on April 12

On April 12 (11:30 am), the node 1 containing soil moisture sensor sense 380 which is up to the optimum level hence the Motor1 is not turned on. Similarly the node 2 containing humidity sensor sense 38 which is also above the optimum level hence the Motor2 is also not turned on as shown in Figures 13 (a) and 13 (b).

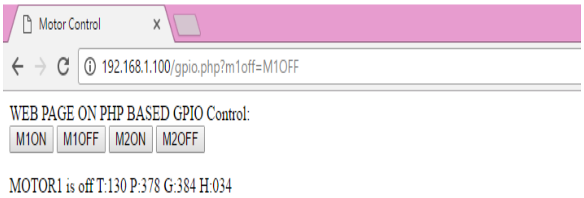

Figure 13 (b) Sensor values and Motor2 OFF at 11:30 am on April 12

On April 13 (8:30 am), the node 1 containing soil moisture sensor sense 472 which is up to the optimum level hence the Motor1 is not turned on. Similarly the node 2 containing humidity sensor sense 52 which is also above the optimum level hence the Motor2 is also not turned on as shown in Figures 14 (a) and 14 (b).

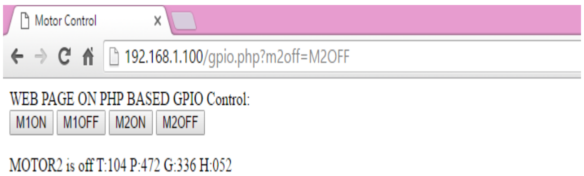

Figure 14 (a) Sensor values and Motor2 OFF at 8:30 am on April 13

Figure 14 (b) Sensor values and Motor1 OFF at 8:30 am on April 13

On April 14 (9:30 am), the node 1 containing soil moisture sensor sense 376 which is up to the optimum level hence the Motor1 is not turned on. Similarly the node 2 containing humidity sensor sense 48 which is also above the optimum level hence the Motor2 is also not turned on as shown in Figures 15 (a) and 15 (b).

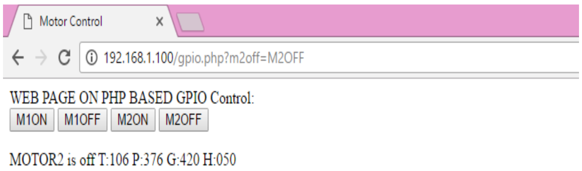

Figure 15 (a) Sensor values and Motor2 OFF at 9:30 am on April 14

On April 14 (12:00 pm), the node 1 containing soil moisture sensor sense 442 which is up to the optimum level hence the Motor1 is not turned on. Similarly the node 2 containing humidity sensor sense 12 which is below the optimum level hence the Motor2 is turned on in order to sprinkle water to the plants as shown in Figures 16 (a) and 16 (b).

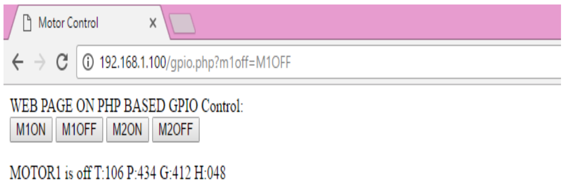

Figure 15 (b) Sensor values and Motor1 OFF at 9:30 am on April 14

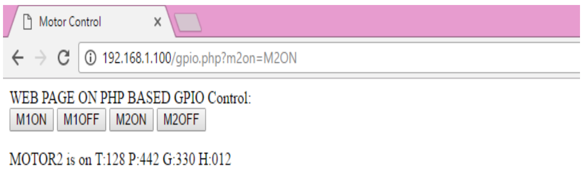

Figure 16 (a) Sensor values and Motor2 ON at 12 pm on April 14

Figure 16 (b) Sensor values and Motor1 OFF at 12 pm on April 14

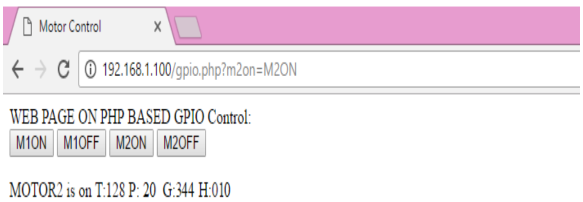

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Figure 17 (a) Sensor values and Motor2 ON at 1 pm on April 15

On April 15 (1:00 pm), the node 1 containing soil moisture sensor sense 20 which is below the optimum level hence the Motor1 is turned on in order to supply water to the plants. Similarly the node 2 containing humidity sensor sense 10 which is also below the optimum level hence the Motor2 is turned on in order to sprinkle water to the plants as shown in Figures 17 (a) and 17 (b).

Figure 17 (b) Sensor values and Motor1 ON at 1 pm on April 15

On May 21 (12:30 pm), the node 1 containing soil moisture sensor sense 260 which is up to the optimum level hence the Motor1 is not turned on. Similarly the node 2 containing humidity sensor sense 08 which is below the optimum level hence the Motor2 is turned on in order to sprinkle water to the plants as shown in Figures 18 (a) and 18 (b).

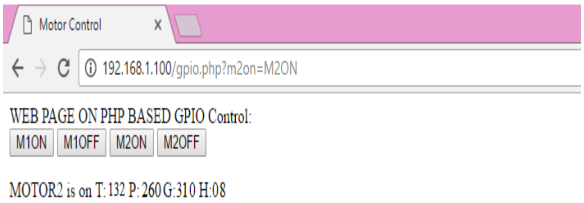

Figure 18 (a) Sensor values and Motor2 ON at 12:30 pm on May 21

Figure 18 (b) Sensor values and Motor1 OFF at 12:30 pm on May 21

On May 22 (4:00 pm), the node 1 containing soil moisture sensor sense 52 which is below the optimum level hence the Motor1 is turned on in order to supply water to the field. Similarly the node 2 containing humidity sensor sense 28 which is also above the optimum level hence the Motor2 is also not turned on as shown in Figures 19 (a) and 19 (b).

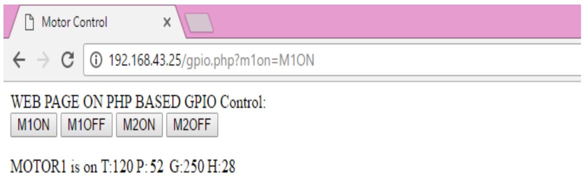

Figure 19 (a) Sensor values and Motor1 ON at 04:00 pm on May 22

Figure 19 (b) Sensor values and Motor1 ON at 04:00 pm on May 22

Since the summer is at peak in May, the temperature is much higher compared to April and the humidity also gets reduced hence the motor is kept on according to the soil moisture and humidity variation.

6. CONCLUSION

In this project, design and implementation of a ZigBee based energy efficient environmental monitoring, alerting and controlling system for agriculture is proposed. Wireless monitoring of field not only allows the farmer to lessen the human power, but it also helps to track the changes accurately happening instantly at the field. The proposed system is capable of controlling the essential parameters necessary for plant growth, i.e. Temperature, humidity, soil moisture and gas etc., viz. watering using motor. Experimental results taken for different dates and different times indicate that the system is reliable.

7. FUTURE WORK

Variable Rate Technology can be built where instead of applying a set rate of fertilizer over the entire field an operator can now apply a rate most effective for a particular section of ground via GPS Map. Vertical farming would replicate the natural environment of agriculture on different floors.

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