DESIGN AND DEVELOPMENT OF LOW POWER SENSOR NODE FOR PLANT MONITORING SYSTEM

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Abstract - *Plant monitoring system is used to monitor the environmental condition in around the plants to have proper growth and maintenance .In the proposed system, a sensor node is designed which runs with battery for longer duration and measuring parameters like temperature, sun light intensity, moisture level and carbon-dioxide. Specially capacitive type moisture level sensor is designed in order to measure the moisture level of the soil. A wireless Sensor network (WSN) is created to sense parameter related to individual plants. Here a MCU having inbuilt 16 bit ADC is used, programmed to transmit the data from using XBee S2C as router. The XBee S2C is configured in low power mode using hardware control. The data transmitted by sensing node will be received by coordinator XBee S2C connected to Raspberry Pi using UART acting as Brain unit. This Raspberry Pi is also connected with CO2 sensor using UART as communication protocol through a 2:1 MUX as Raspberry Pi has only one UART. The data is processed and pushed to the server through Wi-Fi.*

***Key Words*: Plant monitoring system, Sensor node, Capacitive type moisture level sensor, Wireless Sensor Network(WSN), XBee S2C, Arm cortex M0+, Raspberry Pi.**

1. INTRODUCTION

In today's environment, people are surrounded with networked sensors embedded in objects that will respond to their requirements. Now a days people are expecting an intelligent system which are embedded. Due to this a digital environment is created which is so responsive to the people[1].Plant monitoring system have a great demand now a days.

As the technology as been evolved, people are expecting faster system with accurate reading so wireless technology is chosen by everyone. Wireless Sensor Network (WSN) are the most important networks, it consists of spatially distributed autonomous sensors. WSN can monitor physical mediums such as pressure, temperature and sound. Here sensors cooperatively pass their data through the network to a destination or main location [1].

The sensors are the major key components. Sensors have been designed for detection of soil moisture content, temperature, CO2, ph. range in soil, ultra violet radiation, and sunlight intensity.These sensors are small, these small structures can be integrated into many applications related to plant monitoring system. In plant monitoring system, WSN is used for distributing data, collecting and monitoring the necessary environmental information [1].

The plant health monitoring systems are having great demand now a day. By monitoring plant's health we can enrich the productivity. Soil moisture is one of the main factors which is very essential for plant health .The water which is present in the soil in the thin film helps in supplying nutrients to the plant growth [3].

A soil moisture sensor is a type of water sensor. By measuring the electrical conductivity of the ground in which it is buried it works. Better than dry earth wet earth transmits electrical current and by measuring it's conductivity a sensor can detect the presence of water in the soil. The sensor sends a signal to the controller, when the amount of moisture brings the current capacity upto a preset level [4].

The ZigBee (IEEE 802.15.4) is a new wireless technology which permits the implementation of wireless networks .Due to its very low power consumption it is suitable for wireless sensor networks. It as a flexible network architecture, low power consumption, low cost, large number of nodes, so it is more advantageous than other technologies like Bluetooth, Wi-Fi. Here in this project we are using mesh networks. The advantages of mesh networks are self-organizing networks of ZigBee devices, low cost .The components of this networks can operate over extended periods of time ,without changing the original battery they can be over years[5].So here in this project we are using XBee module which is based on the ZigBee technology. Digi International is a company which has developed a module by name XBee module (Digi XBee) by using the ZigBee technology .The first XBee radios were introduced under the MaxStream brand in 2005 and were based on the IEEE 802.15.4-2003 standard designed for point-to-point and star communications at over-the-air baud rates of 250 kbit/s. The XBee radios can all be used with the minimum number of connections -power (3.3 V), ground, data in and data out (UART), with other recommended lines being Reset and Sleep. For the processing and sending the final processed information using inbuilt Wi-Fi to the main sever Raspberry Pi 3 is used at the receiver section.

2. SYSTEM ARCHITECTURE

In this project the proposed system can be divided into two sections:-

1) Sensor node.

2) Brain unit.

2.1 Sensor node

Each sensor node consists of MCU, light intensity sensor, temperature sensor, capacitive type moisture level sensor, router XBee .The block diagram of sensor node is as shown in figure 1.The designed XBee based plant monitoring system consists of multiple sensors namely temperature sensor, light intensity sensor, and capacitive type soil moisture sensor. The system is having a Free scale 32 bit kinetics series microcontroller (Arm cortex M0+) as CPU and also have a rechargeable battery unit that can supply power for the unit for a week (pushing data to the server in 5 minutes interval).The on board battery in transmitter unit can be charged via 5V mobile adapter or USB output of a laptop or P.C. The transmitter unit has a firmware and that will be programmed in embedded C.

All sensors are interfaced to MCU through analog pins as shown in the Figure1. The MCU unit has inbuilt 16 bit ADC , the sensors are connected to 3 channels of ADC and firmware is developed to read the sensor status, process, calibrate and push the data frame through XBEE-S2C using low power mode. The XBee-S2C will be taken to sleep mode for 60Seconds and then woken for a second to push the data frame to XBee-S2C coordinator connected at brain unit. The time delay need to be set once and firmware need to be flashed in MCU present in sensor node. The developed hardware is tested for functionality to sense temperature, soil moisture level & light intensity in degrees, percentage & lumens respectively. The battery backup is tested by setting a rate of data transfer to 60Sec & found to run for duration of 5+ days.

A. Microcontroller

A special interest and attention is given in choosing the microcontroller .Here controller belongs to Kinetis KL25 Sub-Family (KL25Z128VFM4). It is a Cortex-M0+ based microcontroller which is of 48MHz. It has a USB. By keeping efficiency in mind it has been designed.Compatible with all other Kinetis L families as well as Kinetis K2x family .It has General purpose MCU with USB 2.0, featuring market leading ultra low-power to provide developers an appropriate entry-level 32-bit solution. Here in this project the main purpose of using KL25Z128VFM4 is for 16 bit analog to digital conversion and for low power mode in order to design the lower power sensor node.

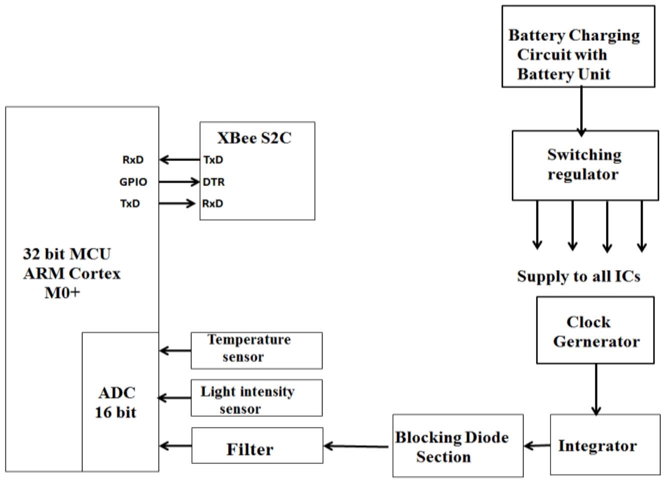

Figure 1: Sensor node of individual plant (transmitter Unit).

B. Battery charging circuit part and switching Regulator part.

In order to have better performance, sensor node depends on the battery backup so battery charging circuit is designed intelligently and is as shown in figure 3.

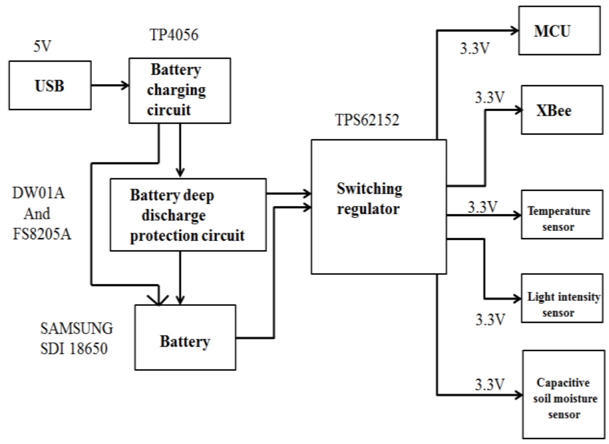

Figure 2: Battery charging part and switching regulator Part.

In the above block diagram the input from the USB is given as input to the battery charging circuit, battery charging circuit as only protection to overcharge but it doesn't have protection against over discharge .So, in order to have protection against deep discharging of battery a deep discharge protection circuit is designed, these two circuits are designed for the battery life protection purpose. The output of battery charging circuit is then fed as input to the switching regulator for the down conversion of output voltage of battery to the required voltage (3.3V).This 3.3V is required to all ICs in sensor node part.

C. Capacitive type moisture level sensor

The block diagram of capacitive type moisture level sensor consists of clock generator, integrator, blocking diode and smoothening filter. The block diagram is as shown below.

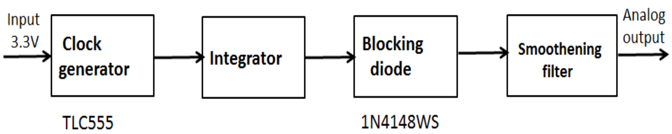

Figure 3: Block diagram of capacitive type moisture level Sensor.

Using TLC555 a pulse is generated, this pulse is fed as input to the integrator. Here integrator is a combination of resistor and variable capacitor .output of this integrator is triangular wave with both positive and negative signal, using blocking diode only positive side is extracted by neglecting the negative side. In order to smoothen the output of blocking diode smoothening filter is used .The analog output of smoothing filter is fed as input to the microcontroller.

2.2 Brain unit

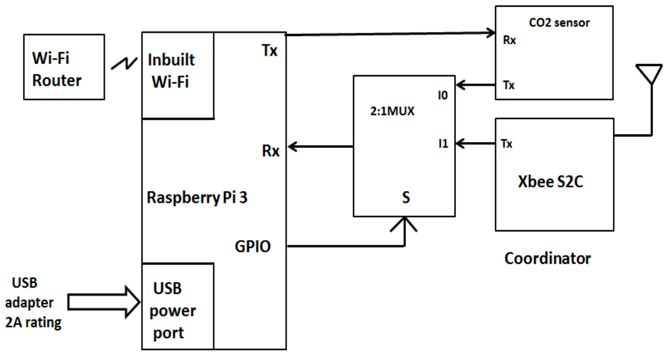

Figure 4: The brain unit (receiver unit).

The brain unit will be consisting of a Raspberry Pi 3 which is connected with designed add-on card. Add-on card consists of CO2 sensor, 2:1 MUX and a receiver XBee-S2C module acting as a coordinator. The whole system will be powered by a 5 volt power supply from mains. The brain unit will be scanning for XBee signals from transmitter unit. The brain unit will be having a python script running over Raspbian O.S which will be receiving, processing and uploading the data received from the transmitter nodes and data coming from CO2 sensor.

As Raspberry Pi 3 is expected to be used, An add on card is designed to multiplex the Rx pin UART protocol in order to interface both CO2 as well as XBee S2C with Raspberry Pi which has single UART port. The XBee S2C and CO2 sensor sequentially use Rx pin of Raspberry Pi by selecting the corresponding input of 2:1 MUX using selection line controlled by GPIO pin of Raspberry Pi. The firmware developed at the Raspberry Pi side does the function of receive data coming at coordinator XBee and push the data to the server using Wi-Fi as well as read CO2 sensor data by sending set of commands and receiving sensor data. The MUX does the function of selecting I0/I1 based on requirement. The overall system architecture of the proposed system looks as shown in figure 5.

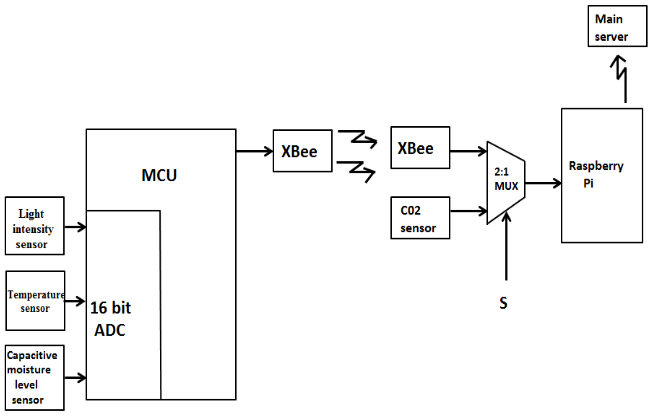

Figure 5: Overall block diagram of the proposed system.

3. HARDWARE IMPLEMENTATION

A suitable hardware circuit for proposed system is designed and this circuit is implemented on the printed circuit board(PCB).PCB designing is done by creating individual libraries for each required hardware components. PCB designing is done separately for sensor node part and for the add-on card. The placement of each component is planned in a well manner so that it consumes less space on the PCB board .Designing and placement of components is fully dependent on the requirements and specifications .After implementation of the hardware module it is tested for it's functionality. The designed 3D view of sensor node PCB looks as shown in figure 6.

Figure 6: 3D view of hardware PCB module of sensor node.

The hardware circuit for the add-on card is also designed and PCB is designed .The 3D view of PCB of add-on card looks as shown in figure 7.

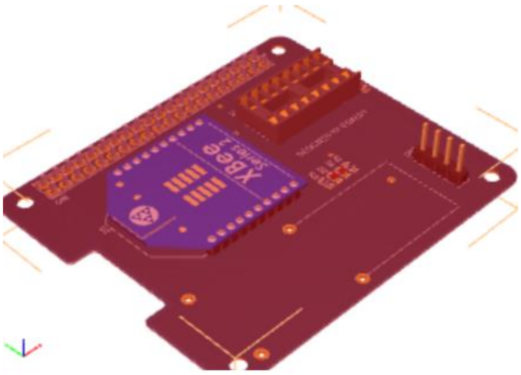

Figure 7: 3D view hardware PCB module of add-on card.

With the help of 40 pin connector present on the add-on card, this add-on card is fitted on the Raspberry Pi module. This setup is made at the receiver side.

4. FIRMWARE FRAMEWORK

At the sensor node side Keil 5 software is used in order to interface all three sensors and XBee S2C module to send the sensed data from transmitter to the receiver. With the help of embedded C language coding is developed for the transmitter side interfacing. The software programming flow at the sensor node side is as shown in figure 8.

At the receiver side Python language is used to receive the sensed data from the transmitter XBee S2C (router XBee) to the receiver XBee S2C (coordinator XBee), process the received information and for the interfacing of add-on card with the Raspberry Pi. The software programming flow at the brain unit side is as shown in figure 9. Both figures 8 and 9 will give the information about the software flow.

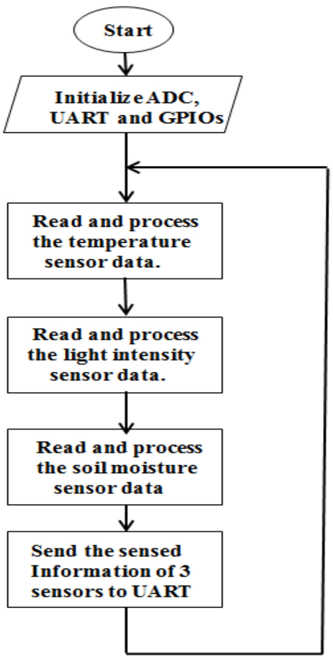

Figure 8: Overall program flow of the sensor node part.

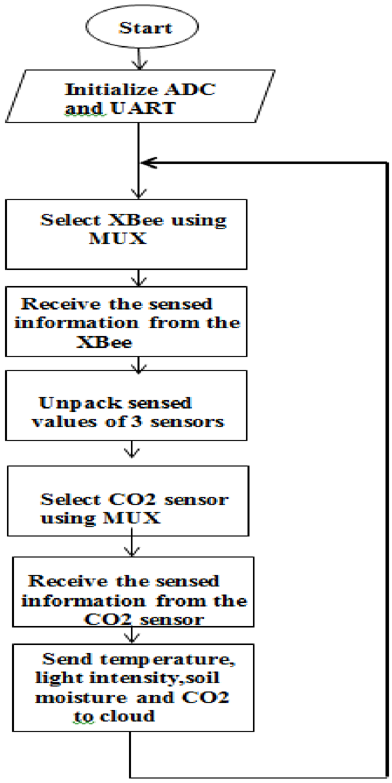

Figure 9: Overall program flow of the receiver part.

5. EXPERIMENTAL RESULTS AND ANALYSIS

The designed hardware module of sensor node is as shown in figures 10.

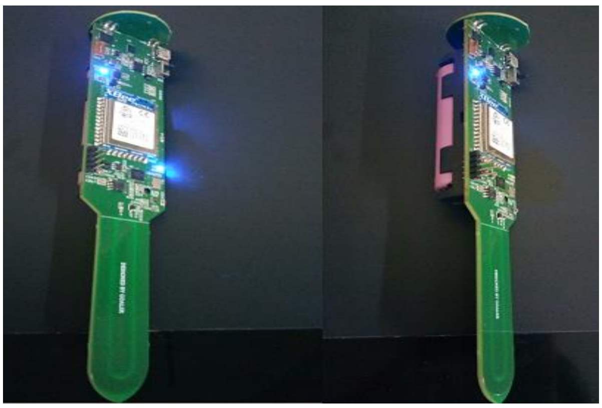

Figure 10: Hardware module of sensor node.

The working of capacitive type moisture level sensor can be tested by dipping the down tip portion of sensor node module into water for testing purpose. The change in voltage with respect to presence of water is as shown in figure 11.When dipped the down tip portion of the module inside water ,it shows less voltage when compared to not dipped into inside water.

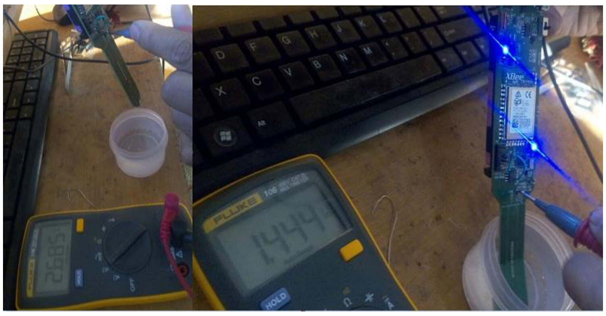

Figure 11: Testing of capacitive type moisture level Sensor

Other sensors are also tested for their good working and their respective results are analysed. After testing, the sensor node module is inserted inside the plant pot in order to monitor a plant .it is as shown in the figure 13.

When the sensor node module dipped in the pot of a plant. The down tip portion is the capacitive moisture level sensor part, depending on the water content present in the soil the capacitance varies as a result due to the change in the capacitance the voltage changes. Meanwhile with respect to change in temperature and sunlight intensity the respective sensors will give their sensed analog output which is fed as input to the MCU unit. This sensed output is processed and send to the receiver part.

Figure 12: Sensor node module dipped inside a plant pot.

Using embedded c language firmware is developed at the sensor node. The firmware developed at the sensor node side will help to send the sensed information acquired from the temperature, sunlight intensity and capacitive type moisture level sensors wirelessly with help of transmitter XBee S2C to the coordinator XBee. Here firmware is developed to read the sensor status, process, calibrate and push the data frame through XBee-S2C to receiver part using low power mode. The battery is tested with different data pushing rate with and without low power modes of XBee S2C node at the sensor side.

Figure 13: Brain unit module.

At the brain unit side as the Raspberry Pi is used, using Python firmware is developed which is running over Raspbian OS which will be receiving, processing and uploading the data received from the transmitter nodes and data coming from the CO2 sensor to the main server through inbuilt Wi-Fi.

Figure 14 shows the final output of Raspberry Pi, which gives the information about the monitored parameters .this information is pushed to the sever through inbuilt Wi-Fi of Raspberry Pi.

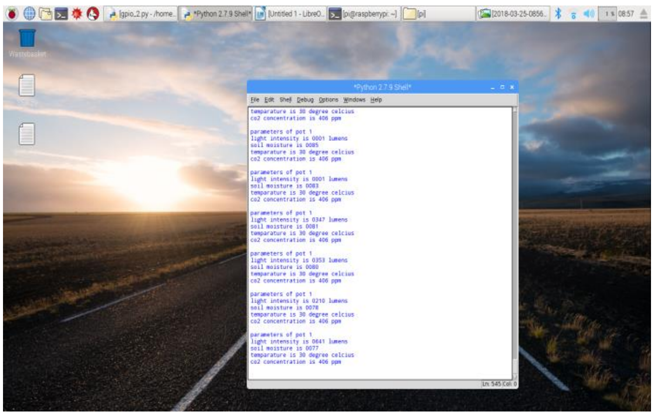

Figure 14: Output of receiver side (Temperature, sunlight Intensity, soil moisture and C02 sensors response).

6. CONCLUSION

A low power sensor node designing and implementation for a IoT based plant monitoring system is studied in this project. With the help of temperature sensor, light intensity sensor and capacitive type moisture level sensor, individual plants are monitored and the sensed information is processed with the help of MCU and transmitted with the help of XBee S2C in low power mode .With the help of coordinator XBee S2C the transmitted information is received and the received information along with CO2 sensor data is processed with the help of Raspberry Pi 3.With the help of inbuilt Wi-Fi the data is pushed to the server ,from the sever the data can be retrieved anywhere and at any time as required by the owner of the plant. This project tends to an evolved smart way of plant health monitoring system using low power wireless communication.

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