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Development of low power and cost-effective Unified Wireless Sensor Node-SRMsense for precision agriculture

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ABSTRACT

As a part of the field monitoring system, many systems were developed for measuring or inferring soil and crop parameters on both proximal (ground level) and remote (aerial) platforms. The purpose of this work is to develop a low-cost wireless physical parameter sensing and computing device to address the issues concerning agriculture. The core of the SRMsens is based on the 8-bit AVR microcontroller (Atmega168PU), 2.4 GHz wireless transceiver (ZigBee) and Wi-Fi module (ESP8266) and sensors such as temperature sensor, Humidity sensor, air quality sensor, soil moisture sensor and PH sensor. High levels of power efficiency is achieved by using IEEE 802.15.4 (ZigBee) which in establishing communication between wireless nodes - SRMsens by forming an ad-hoc network between the nodes. The Wi-Fi module in SRMsens extends the capability to make IoT-based applications. The main advantage of the design is it used with many IDEs like Atmel Studio, Arduino IDE or using command line terminal with AVR toolchain installed. The network formed with the help of the wireless node is bidirectional communication and control of inter-node data pack reception designed for used for any application that requires continuous monitoring of sensed data like pollution level, noise level, and temperature etc., . The ultimate goal of this research is to deploy the cost effective solution for precision agriculture ,to monitor the soil moisture-temperature through Internet in order to utilize the resources required for the ground efficiently.

Keywords: wireless sensor node, ZigBee, Atmega168PU, ESP8266, IoT,precision agriculture.

1. INTRODUCTION

The pursuit of farmers is larger and more predictable harvest from the same fields with reduced use of fertilizers and chemicals and spending as little as possible in the same field. Precision Agriculture is an integrated information and yield based farming system that is designed to increase long-term, site-specific and whole farm production efficiency and profitability while minimizing unintentional impacts on wildlife and the environment. [10] In other words, precision agriculture is a farm management strategy which utilizes the benefits of information technology and to improve production and minimize environmental impact. By implementing precision agriculture methods for farming, prediction of soil parameters can be achieved which may lead to reduced use of fertilizer and chemicals.

There is a need to develop a physically embedded computing device, which consumes less power and also cost-effective [11]. This kind of embedded computing device known as wireless sensor node (mote). These devices must be scalable for large scale deployment to and also able ability to withstand harsh environmental conditions.

Advancement in Micro Electro Mechanical Systems (MEMS) and RF communication systems has made wireless sensor network applicable for industrial and commercial applications. Mote developed consist of low power sensors for acquiring raw data's from the fields and ZigBee (IEEE802.15.4) Transceiver for communicating the sensed data in full duplex communication and control of inter-node data reception.

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This is the requirement for continuous monitoring of data like pollution level, noise level, and temperature [3]. The Wi-Fi module embedded in the coordinator mote uploads the data retrieved from the sensor to the Cloud and the uploaded data can we viewed from anywhere, at any place and at any time. Generally, motes are powered using batteries, if the batteries drain out, it gets isolated from the wireless network. In order to overcome this disadvantage, the mote developed contains a solar panel which provides uninterrupted power supply to mote. There is a need to develop a physically embedded computing device, which consumes less power and also cost-effective [11]. This kind of embedded computing device known as wireless sensor node (mote). These devices must be scalable for large scale deployment to and also able ability to withstand harsh environmental conditions.

2. MOTIVATION

According to the statistics of World Bank, the total arable land area, which is under cropping and permanent pastures in India is 67.7%, where as in China only 34%. As per wall street journal report on world's agricultural yield, India's contribution to rice, wheat and fruits production is less than China [1].Since the population of India is increasing; the country has to adapt new technologies to enhance production and to reduce agricultural imports. To increase the productivity, we cannot improve the farmland, but we can use the farmland by monitoring the crops and soil parameters. The more efficient way to monitor crops and soil continuously, by creating a device that fit for agriculture needs and cost effective with a high communication range for data transmission to the other devices. To address this issue, there were some wireless sensor motes, such as MicaZ, TelosB, IRIS etc. are available in the market [2]. These motes are either too costly or consume more power when compared to each other. ZigBee used in this mote is a long range ZigBee, which can cover a distance of 1.6Km (outdoor range), whereas other motes like telosB, micaZ, etc. has only a few meters of range. The mote has a total on-chip memory of 16k RAM with 512k external memory and a frequency speed of around 2.4 GHZ in a data rate of 250 kbps. One of the main drawbacks of another wireless sensor mote is ease of using the mote but draws more knowledge on an operating system and integrated development environment. SRMsens- can be used with any operating system with AVR tool chain installed and it be used with Arduino IDE. This mote has a wide range of sensors which helps to deploy this mote directly in agricultural fields. Some of these sensors are Temperature, Humidity, and Co2, and we can also add sensors externally as per the requirement of our agriculture needs.

3. SYSTEM ARCHITECTURE

This section shows the basic architecture of SRMsens. The major units of this wireless sensor mote are data processing RF communication unit, sensing unit, power supply unit.

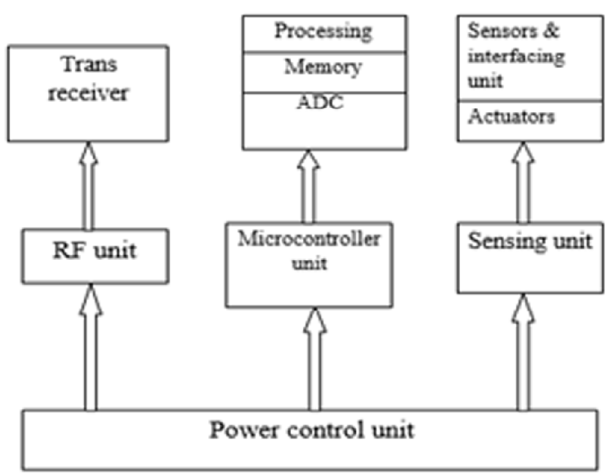

Figure 1: Functional Block Diagram of Wireless Sensor Node

On looking deeper into the developed system the block diagram motes function diagrams as in figure 1 Figure 2, gives the blocks of SRMsens –Wireless Sensor Node.

3.1. Power supply

Mostly the wireless sensor motes developed is always deployed in a hard to reach location, changing the battery frequently makes inconvenient and costly. So a mote should be developed in such a way, it should always have adequate energy available to power the system. Here the mote designed has two 3.3v AA rechargeable alkaline batteries is powered by using a solar panel so that we can provide an uninterrupted power supply to the mote.

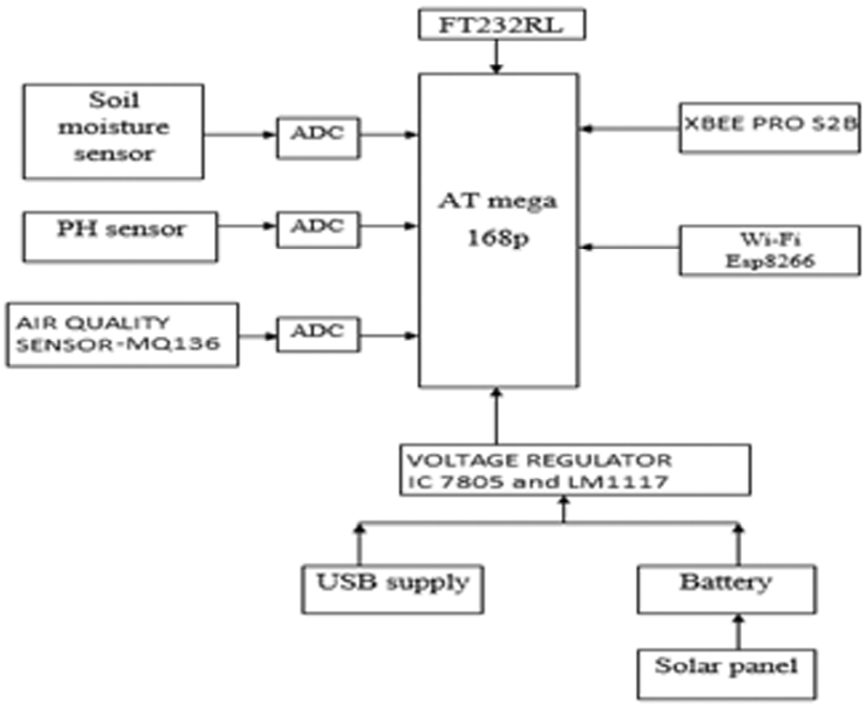

Figure 2: Functional Block diagram of SRMsens

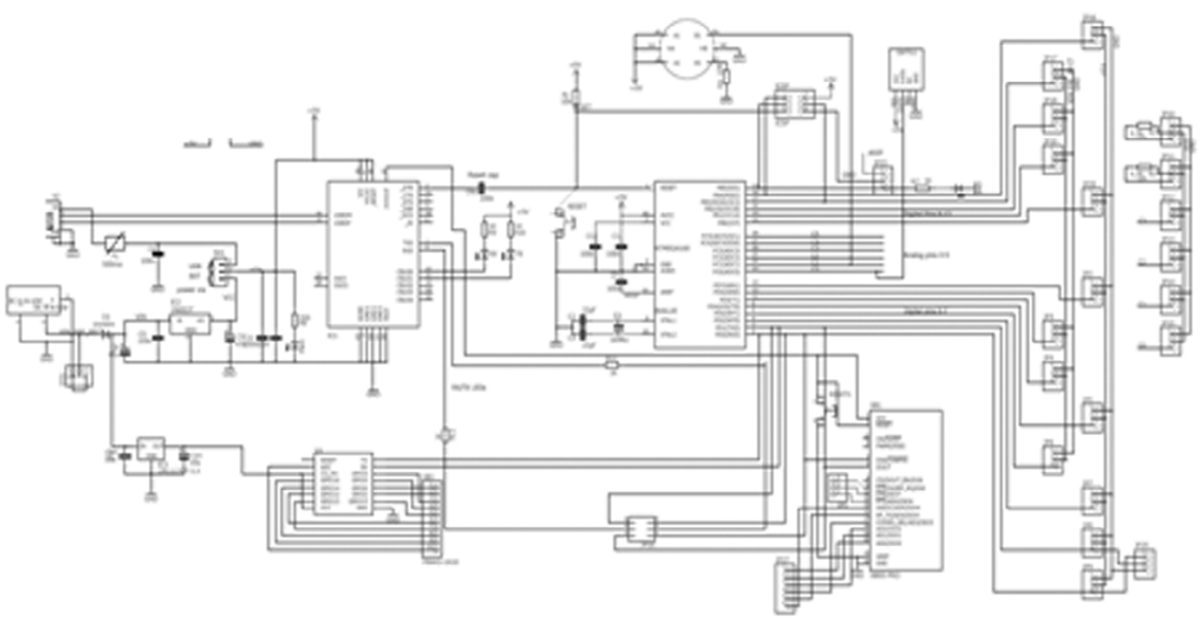

Figure 3: Schematic of SRMsens-Wireless Sensor node

3.2. ZigBee

ZigBee Architectures or Protocol is a standard aims to simplify the integration of wireless networking capability into embedded devices and is particularly suited for wireless sensor network applications [3]. It is based on the 802.15.4 physical radio standard, and ZigBee devices operate within the unlicensed 2.4GHz band. Since this band is shared by some other wireless systems, there is potential for interference with other devices. ZigBee inherently transfers a low volume of packets, which minimizes the potential for clashes in the first place, but additionally can operate on 16 distinct channels and employs collision avoidance techniques (CSMA-CA) to ensure further reliability [3]. It is developed to address the major issues such as low power and low cost in wireless sensors network. It provides support for concurrency at Physical layer and the MAC sub-layer using with Application. The Network layers act as an upper layer, along with some added network that enables the bi-directional communication using more cost efficient and minimal energy consuming for battery powered devices [3]. However, it has a raw data throughput of 250Kbps, which is more than adequate for wireless sensor network applications, but is slower than Bluetooth and much slower than Wi-Fi.

A ZigBee can be one of three different types of node configuration. The configurations are End device, Router, and Coordinator. There can be exactly one coordinator in each system, and it forms the network among the interconnections. It can store information about the network, including security keys .Routers act as an intermediate nodes, relaying data from other devices .End Devices can be low-power or battery-powered devices. Where they have got sufficient functionality to talk to their parents (either the coordinator a router) and cannot depend on the data from other intermediate ZigBee. This reduced functionality allows reducing their cost.

3.3. Wi-Fi module

The Wi-Fi Module that we are using here is ESP 8266, the cost of the module is around 4$ which is less compared to other modules and using this module we can connect to cloud and upload our data and these data can monitor from anywhere through web server[5]. Here some of the unique features of esp8266 are

- Wake up and transmit packets in less than 2ms
- Standby power consumption of less than 1.0mW.
- Supports antenna diversity
- Wi-Fi Direct (P2P), soft-AP
- Cost effective as compared to other Wi-Fi modules.

3.4. Microcontroller

It is a High Performance, Low Power Atmel AVR8-Bit Microcontroller. It is based on Advanced RISC Architecture.it has 131 Powerful Instructions. Most Single Clock Cycle Execution. The controller consist of 32 × 8 General Purpose Working Registers which is Fully Static Operation[4].

This microcontroller has high Endurance Non-volatile Memory Segments, with 4/8/16KBytes of In-System Self-Programmable Flash, program memory–256/512/512Bytes EEPROM, 512/1K/1Kbytes of Internal SRAM storage, Write/Erase Cycles: 10,000 Flash/100,000 EEPROM. It contain special feature of Data retention: 20 years at 85°C/100 years at 25°C and also Optional Boot Code Section with Independent Lock Bits in System Programming by On-chip Boot Program with True Read and Write Operation[4]. The different peripherals in this microcontroller are Two 8-bit Timer/Counters with Separate Rescale and Compare Mode, one 16-bit Timer/Counter with Separate presales, Capture Mode, and Compare Mode along with Real Time Counter with Separate Oscillator, Six PWM Channels,8-channel 10-bit ADC in TQFP and

QFN/MLF package. It also has 6-channel 10-bit ADC in PDIP Package, with a Programmable Serial USART, Master/Slave SPI Serial Interface, which is Byte-oriented 2-wire Serial Interface (Philips I2C compatible), Programmable Watchdog Timer with Separate On-chip Oscillator, On-chip Analog Comparator, Interrupt and Wake-up on Pin Change[4].

The Special Microcontroller Features are Power-on Reset and Programmable Brown-out Detection, External and Internal Interrupt Sources, Internal Calibrated Oscillator, Six Sleep Modes: Idle, Power-save, Standby, ADC Noise Reduction, Power-down, and Extended Standby. The I/O and Packages are 23 Programmable I/O Lines and 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF[4].

The Operating Voltage is around 1.8 - 5.5V for Atmega48P/88P/168PV and Atmega48P/88P/168P has around 2.7 - 5.5V for .the temperature Range for the controller to operate is 40Celsius to 85Celsius. The Speed Grade of the controller is

- ATmega48P/88P/168PV: 0 - 4MHz @ 1.8 - 5.5V, 0 - 10MHz @ 2.7 – 5.5V as input voltage
- ATmega48P/88P/168P: 0 - 10MHz @ 2.7 - 5.5V, 0 - 20MHz @ 4.5 - 5.5V as input voltage

Low Power Consumption is achieved at 1MHz, 1.8V, 25 with Active Mode power consumption 0.3mA, Power-down Mode consumption 0.1µA and Power-save Mode consumption 0.8ìA (Including 32kHz RTC).

3.5. Sensor

The most important aspect is to know the parameters requirements for precision agriculture and to connect the hardware that sense those parameters, here are some of the required parameters that are necessary are Soil Moisture (Centibars), Temperature (Degree Centigrade), Relative Humidity (Percentage), Carbon Dioxide (Parts per million).

In order to detect these parameters, we use sensors that are mentioned below:

1. Temperature and Humidity sensor
2. Gas sensor
3. Soil moisture sensor

We fabricated the board with temperature and humidity sensor along the gas sensor which measures CO_2, which forms an on board sensor and we connect soil sensor externally using.

We use DHT11 which is Low cost and consumes power around 3 to 5V and Input and output current of 2.5mA max during conversion (while requesting data).this sensor can calculate humidity range of 20-80% humidity readings with 5% accuracy and can calculate the temperature around 0-50°C temperature readings ±2°C accuracy with a sampling rate of not more than 1 Hz (once every second).

We use MQ-135 gas sensor this is used in air quality control equipment, where we can use this in agriculture study on crops by detecting the favorable gases that are required. This sensor is suitable for detecting of NH3, smoke, CO2, NOx, alcohol, Benzene, etc. But it can detect only during Standard Detecting Conditions which are as described

- Temp: 20±2 Vc:5V±0.1
- Humidity: 65%±5% Vh: 5V±0.1

The soil moisture sensor that we use externally is YL-69. This is an Electrical Resistance Sensor. The sensor is made up of two electrodes. This soil sensor reads the amount of moisture content in a field or any particular soil condition around it. A current is passed between the electrodes through the soil and the resistance towards the current from the soil determines the soil moisture.

If the soil has more water resistance will be low and thus high amount of current passes through the electrodes. On the other hand, when the soil moisture is low the sensor module outputs a high level of resistance. This sensor has both dual digital as well as analogue outputs. Digital output is simple to use but is not as accurate as the analogue output.

The sensor comes with a small PCB board fitted with LM393 comparator chip and a digital potentiometer.

4. IMPLEMENTATION

The mote can be powered through the USB port or with an external power supply through solar panel. The power source is selected manually. The logic for manual selection is shown in the fig, in order power the device using USB supply, a jumper has to be connected from USB supply pin to controller supply pin. Similarly, to power the mote using solar panel, connect the jumper from controller supply to external source. The external supply for the mote through solar panel is in the range of 7 to 12 volts. Because, if supplied voltage is less than 7V, the 5V power might supply less than five volts at that time the mote may become unstable. If the input voltage is greater than 12V, the voltage regulator gets heated, which results in the damage of the board.

The power requirement for XBee and Esp8266 is 3.3V, so LM1117 (3.3V voltage regulator) is added to the power supply unit to power these two devices separately. If 5V supply is given directly to the device, there is more probability for the device to get damaged. The Atmega168P is interfaced with Xbee pro s2b and ESP8266 through the serial port. The serial port allows synchronous data transfer between the Atmega168p and xbee or between Atmega168P and ESP8266.if the power consumption requirement for a particular application is too low there is a provision to directly bye pass the controller and use ZigBee alone to transmit to the coordinator node. The programmable baud rates allows the user to operate at required speed.

Based on the Xbee configuration in the wireless sensor mote, it is designated as coordinator, router or as an end device. In order to configure Xbee, we need to give USB access for the Xbee and disconnect ATmega from the USB. So that only one device can drive the USB bus wire at a time.in order to address this issue, having jumpers to connect the devices individually is the most efficient method. The implementation is shown in the fig 5.

The basic circuit to make AVR microcontroller work at start is given below.

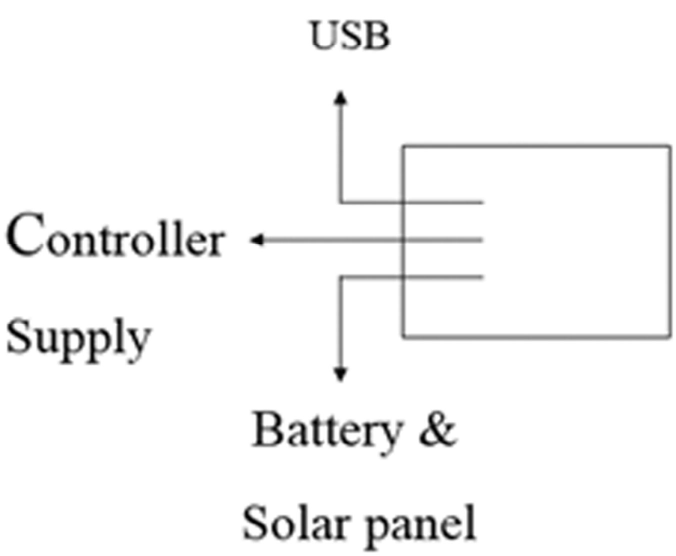

Figure 4:

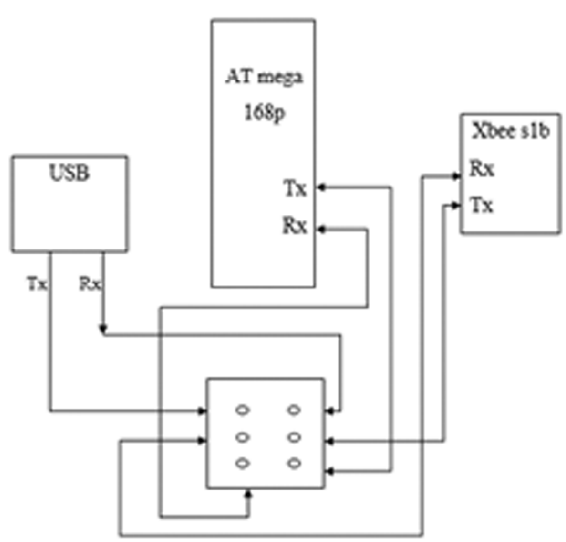

Figure 5:

The controller requires a 16MHz crystal oscillator, interfaced at XTAL1 and XTAL2 pins with 22pf capacitor at each pins.

The RESET pin on the microcontroller is active LOW. Which means setting the pin LOW externally will reset the microcontroller. The main purpose of RESET is to release all lines by tri-stating all pins (except XTAL pins), initialize all I/O registers and set program counter to initial position.

The atmega168p ‘s major responsible for initializing the system, receiving and executing the data.

The operation of the controller can be divided into five parts: (1) initialize the system clock, RTC, Serial Port, ZigBee, ESP module. (2) The Processor consumes low-power and waits for the switch from the UART. (3) The data entering through the serial port will put the processor in normal operating mode.it can also find and manipulate the data which enters through the serial port. (4) it concludes whether the data

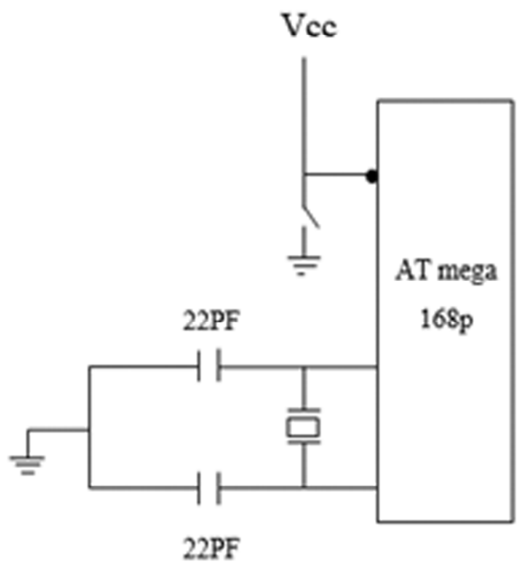

Figure 6:

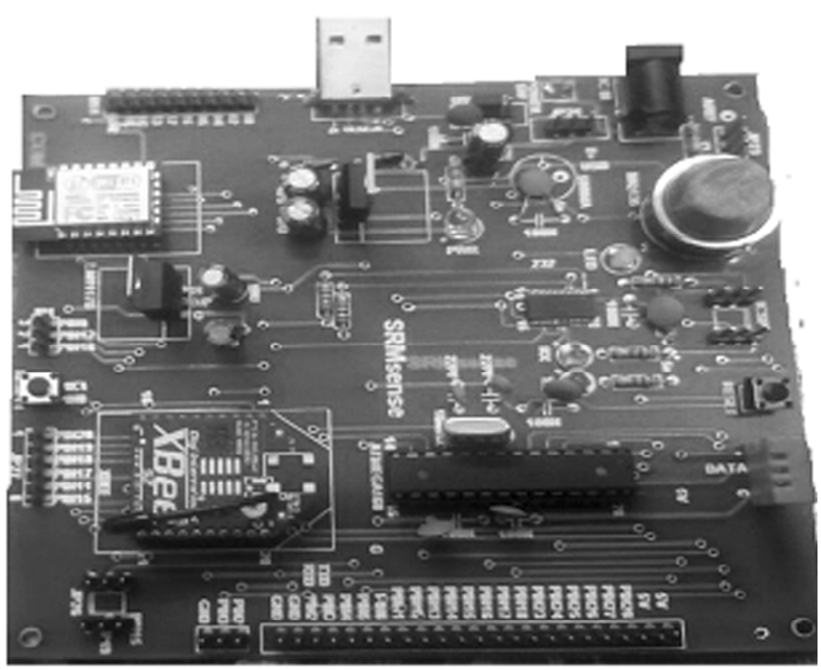

Figure 7: SRMsense development board

received through the serial port is useful or not, if it is not useful the processor returns to the low-power-consumption mode and waits for the serial port data, if the data entering is useful, the processor decodes and identify them and decide the content (5) On controlling the peripherals, the processor can setup the timer and measure the parameters which is required. After the operation, the processor returns to the low power-consumption mode and waits for the data input through the serial port.

5. CONCLUSION

Now a day, wireless sensor network has become as most promising technologies due to the capability of remote sensing and data gathering ability. It is capable of computing at the local site and also can communicate wirelessly over a certain range. This mote can also be used in many aspects, such as traffic control, agriculture and disaster management etc by interfacing appropriate sensors externally. The wireless sensor developed is very easy to implement and practical, since it can be coded with most well-known platforms like Arduino, Atmel studio or through Linux terminal. After becoming familiar with the basics of implementing this mote in WSN application, it is easy to build complex networks and applications using the same principles. The most important thing is to be able to read the data from the sensor, transmit it to the coordinator site, and analyze the data using the required software tools in the computer, by retrieving the datas from coordinator through internet. In future, advanced features and configurations such as changing the rate of sampling based on the type of triggering factor and increasing the transmission rate between the motes, upgrading MAC layer protocol which might help the mote to form energy efficient networks. These advanced features increase the efficiency of the network.

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