SELF SUSTAINABLE WIRELESS SENSOR NETWORK FOR AGRICULTURE

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Abstract: Agriculture plays a vital role in India's economy. Over 58 per cent of the rural households depend on agriculture as their principal means of livelihood. Agriculture contributes to 17% of the Gross Domestic Product (GDP) in Indian economy. Most of the rural farmers rely on improper farming practices. With the water requirement in the farming, there is a need of irrigation system that can save water. Super flaws irrigation leaches nutritive element of soil as water seeps down due to gravitational force of earth. It also causes water logging, so irrigation need a constant monitoring. The improvement in irrigation system using wireless network is a solution to achieve water conservation as well as improvement in irrigation practices.The dissertation aims to implement sensor based irrigation system through wireless sensor networks. The objective of this project is to control the flow of water in pipe with the help of soil moisture sensor. Depending on the need of plant or crop water will be supplied automatically by implementing a carbon nano tube based low cost soil sensor design. Thus system is providing self-sustainable wireless sensor network for plant irrigation. This irrigation allows farmer to reduce run-off from over-water in saturated soil and also reduces water wastage and in effect improve the crop yield by ensuring adequate water supply when needed.

Keywords - carbon nanotube.nodemcu,ardiuno,zeegbee ,gpio.

I. INTRODUCTION

Agriculture plays a vital role in India's economy. Over 58 per cent of the rural households depend on agriculture as their principal means of livelihood. Agriculture contributes to 17% of the Gross Domestic Product (GDP) in Indian economy. Most of the rural farmers rely on improper farming practices. With the water requirement in the farming, there is a need of irrigation system that can save water. Super flaws irrigation leaches nutritive element of soil as water seeps down due to gravitational force of earth. It also causes water logging, so irrigation need a constant monitoring. The improvement in irrigation system using wireless network is a solution to achieve water conservation as well as improvement in irrigation practices.The dissertation aims to implement sensor based irrigation system through wireless sensor networks. The objective of this project is to control the flow of water in pipe with the help of soil moisture sensor. Depending on the need of plant or crop water will be supplied automatically by implementing a carbon nano tube based low cost soil sensor design. Thus system is providing self-sustainable wireless sensor network for plant irrigation. This irrigation allows farmer to reduce run-off from over-water in saturated soil and also reduces water wastage and in effect improve the crop yield by ensuring adequate water supply when needed.

II. SURVEY OF LITERATURE

Walker [1], in his paper titled surface irrigation evaluation and design has presented the surface irrigation method in which water is distributed over the field by a free-surface, gravity flow [1]. A flow is introduced at a high point or along a high edge of the field and allowed to cover the field by overland flow. The rate of coverage is dependent entirely on the quantitative differences between inlet discharge and the accumulating infiltration. Secondary factors include field slope and length as well as surface roughness. The surface irrigation systems are typically less efficient in applying water than either sprinkle or trickle systems. Land levelling costs are high, so the surface irrigation practice tends to be limited to land already having small, even slopes.Skaggs [2], in his paper titled Drip Irrigation: Implications and obstacles has proposed Drip irrigation which saves water by allowing water to drip slowly to the roots of many different plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing and emitters. It is done through narrow tubes that deliver water directly to the base of the plant. It is chosen instead of surface irrigation for various reasons, often including concern about minimizing evaporation. Drip system requires constant maintenance and monitoring. Emitters can become clogged and leaks can develop as result of mechanical or animal damage. Salt can accumulate near the root zone. Seeds may not germinate in the fields where drip irrigation cannot be supplemented by surface or sprinkler irrigation early in growing Season. Microclimate control is reduced as a result of drip irrigation, while surface or sprinkler irrigation can lower air temperature around growing plants and thus reduce water stress and transpiration.Scherer[3], in his paper titled Sprinkler Irrigation System has presented Sprinkler irrigation method of applying irrigation water which is similar to natural rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. Seepage Losses, which occur in earthen channels of surface irrigation methods, are completely eliminated. Moreover, only optimum quantity of water is used in this method Land levelling is not required and thus avoiding removal of top fertile soil, as happens in other surface irrigation methods. The water is to be applied at a rate lesser than the infiltration capacity of the soil, and thus

avoiding surface run off. This method leaches down salts and prevents water-logging or salinity. Hence this project implements the sprinkler irrigation technique.uthor in [6] applied Gabor wavelet and Discrete Cosine Transform to extract the color and texture feature whereas Manhattan distance was used as similarity metric. [7] adopted color histogram and helped to enhance the retrieval accuracy [12].

III. PROPOSED METHODOLOGY

3.1 System Overview

Fig 3.1 shows the functional block diagram of the project

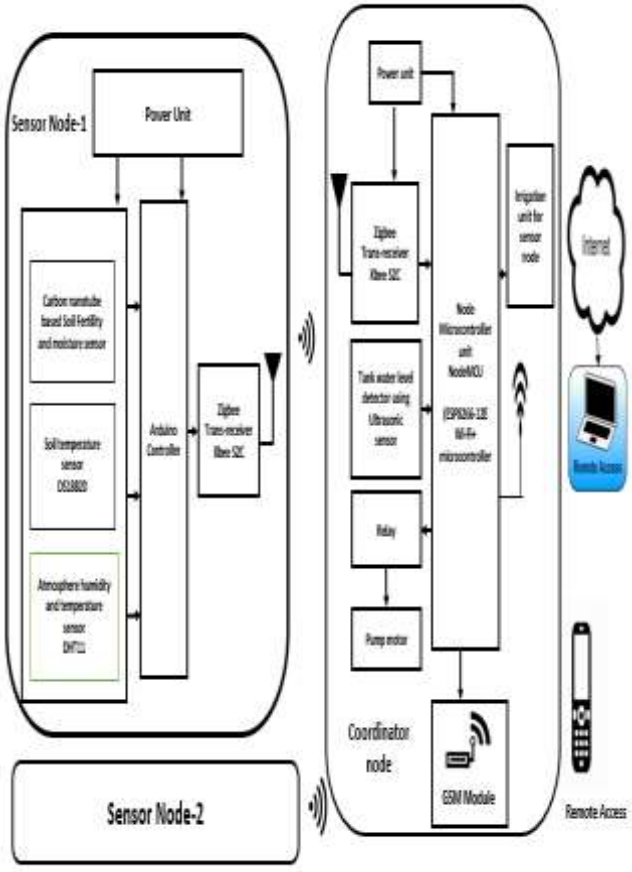


Fig 3.1 System Overview

System mainly aims at reducing the wastage of water and minimizing the manual labour on field for irrigation. The wireless sensor network consists of multiple devices which are capable of computation, communication and sensing. The system can be classified into three main categories: -

(a) End Device Node consisting of intelligent sensors, Arduino controller, Zigbee.

(b) Coordinator Node consisting of Node MCU, Zigbee Module and alert system.

(c) Irrigation control unit.

In the system, agricultural land is divided into sensor nodes. Each end device node has temperature sensor, humidity sensor, soil moisture and fertility sensor which senses the data and provides the corresponding output to the Arduino microcontroller. This data is transmitted to the coordinator node using Zigbee wireless protocol. Coordinator node manages all the sensor node in the farm field. It receives the data from each sensor node using Zigbee module. Coordinator node consist of a NodeMcU module as node microcontroller unit. NodeMCU consist 32bit microcontroller and ESP8266 Wi-Fi module. Data received by Zigbee from various sensor nodes is provided to the NodeMCU which processes the acquired data.

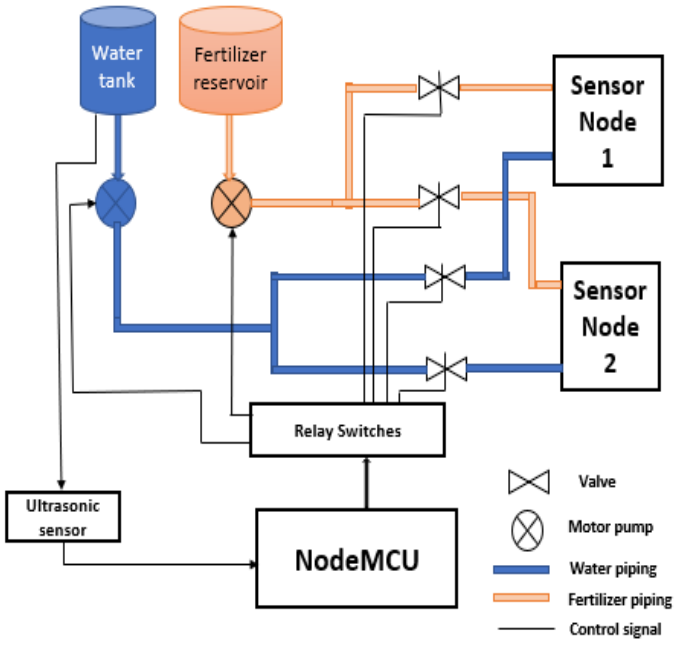


Fig 3.2 Irrigation Unit layout

When any of the above-mentioned parameters cross a safety threshold NodeMCU performs the required action by turning on the relays to provide water or fertilizer supply to particular area in the farm field until the parameter has been brought back to its normal level. GPIO pins of Node MCU are connected to particular valve through relay switch for particular filed area. Pump Motor is also connected to GPOI pin of Node MCU through relay switch. Undernormal condition relay switch turns off and the water stops flowing into the field. This ensures that the right amount of water is provided to the crops and water is not flooded. Required fertilizer is also provided by this system. NodeMCU also senses the data from ultrasonic sensor. The ultra-sonic sensor is used to indicate the water-level in the tank. This indicator makes sure that enough water is always available in the tank. If water is not sufficient irrigation unit will be turned off. The detailed Irrigation layout is shown fig3.2 NodeMCU sends the sensor data to the IoT web server by using the Esp8266 Wi-Fi transceiver module. The IoT cloud server we can analyze the sensor data in the form of graphs and access these values anywhere and anytime using internet connections. System also provides a indication about the abnormal conditions like decrease in fertility level or soil moisture level to farmer with a short message service (SMS) via GSM service to registered mobile number. This service is provided for convenience of farmer who cannot handle IoT web server.

3.2 Component description

3.2.1 Node MCU

NodeMCU is an open source IOT platform. It includes firmware which runs on the ESP8266 Wi-Fi SOC and hardware platform which is based on the ESP-12 module.

Integrated hardware based on ESP8266, integrates GPIO, PWM, IIC, 1-Wire and ADC all in one board

- USB-TTL on board.
- 10 GPIO, every GPIO can be PWM, I2C, 1-wire.
- ESP8266-12E WIFI module
- PCB antenna.

Fig.3.3 NodeMCU

ESP8266 12-E (microprocessor & Wi-Fi module*):* Serial Wi-Fi Wireless Transceiver microcontroller module. It is 80 MHz microcontroller with a full Wi-Fi front-end (both as client and access point) and TCP/IP stack with DNS support as well comes with a 4MB flash chip, an ESP processor, and an onboard antenna. ESP8266-12E also integrates an enhanced version of Tensilica's L106 Diamond series 32-bit processor, with on-chip SRAM . The module consumes less power and its Deep Sleep technology enables it to go to sleep for a certain specified interval, making the power consumption very low and making it a perfectbattery powered solution. The programming of the microcontroller is done in Lua.

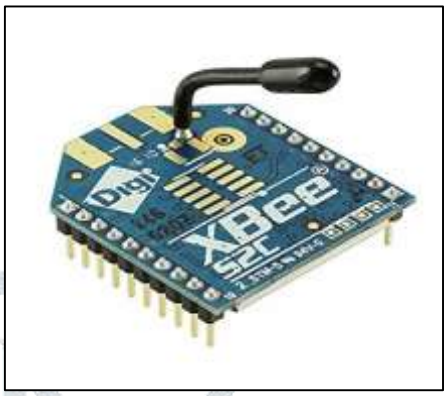
3.2.2 Zigbee Module :Xbee S2C

A ZigBee protocol for wireless communication which isbased on the underlying protocol IEEE 802.15.4, which definesthe network physical layer, and controlling layer for mediaaccess, while ZigBee protocol defines the network layer, application layer and specifications of the network securityservices.Zigbee 802.15.4 RF modules are of XBeefamily, looking for excellent wireless performance. The low cost allows the technology to be widely deployed in wireless control and monitoring applications. ZigBee device can be used in many useful areas like Industrial, scientific and medical field and it has 2.4 GHz Radio Band. The functionality of both transmitter and receiver combined into a single device known as a transceiver. ZigBee transceivers are used for transmission and reception purpose. The modules are easy-to-use, require minimal power and provide reliable delivery of critical data between devices. Its small form factor saves valuable board space. XBee modules are available with a PCB chip antenna, a ¼ monopole integrated whip antenna, or a U. FL antenna connector that allows for connection to a dipole or other external antenna. It has following specifications.

- Operating Voltage: 2.1 – 3.6V
- Operating Current: 40mA@3.3V
- Indoor range: 40 Meters
- Line of sight range: 120 Meters
- Max Analog Pin Reading: 1.2V
- Digital I/O pins: 11
- Analog input pins: 4
- RF Data Rate: 250kbps
- Throughput speed: 35kbps
- Frequency: ISM 2.4GHz
- OK Temp: -40 to 85C

Networking:

- Spread Spectrum Type:DSSS (Direct Sequence Spread Spectrum)
- Networking Topology:Peer-to-peer, point-to-point & point-to-multipoint
- Filtration Options:PAN ID, channel and addresses
- Channel Capacity:16 Direct Sequence Channels (software selectable)
- Addressing:65,000 network addresses available for each channel



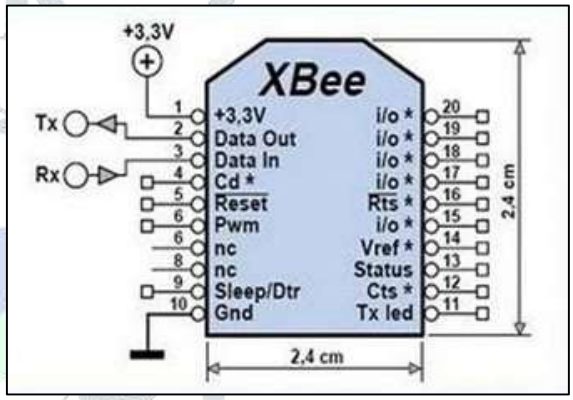


Fig.3.4 Xbee S2C module

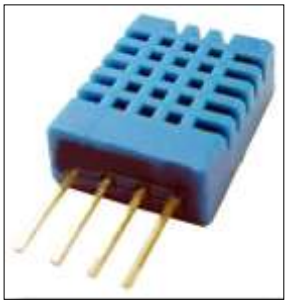
Fig.3.5 Xbee Pin configuration

3.2.3 DHT11 (Temperature & Humidity Sensor)

Digital Humidity & Temperature sensor are programmed with the microcontroller for capturing humidity and temperature from DHT11 DHT sensor features calibrated digital signal output. By using the digital signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellentlong-term stability. This sensor includes a resistive-type humidity measurement component and a negative temperature coefficient-based temperature measurement component.

- Low cost.
- to 5V power and I/O.
- Good for 20-80% humidity readings with 5% accuracy.
- Good for 0-50°C temperature readings ±2°C accuracy.
- No more than 1 Hz sampling rate (once every second).

The component is 4-pin single row pin package. It is convenient to connect and special packages can be provided according to users' request.



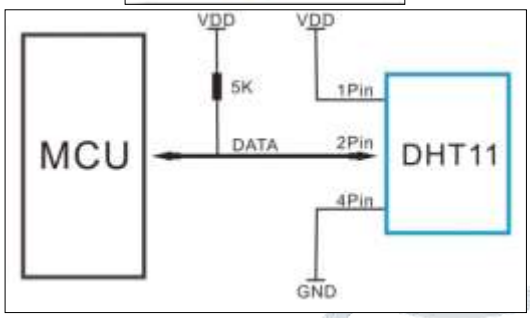


Fig.3.6DHT11 sensor Fig.3.7 Typical application of DHT11

3.2.4 Carbon Nanotube based Soil sensor

In Agriculture one of the important sensor is Soil fertility sensor. Some systems make use of moisture sensor and expensive soil pH sensors to measure water content and soil fertility respectively. The proposed System uses carbon nanotube-based soil fertility sensor which gives combined effect of both soil moisture and fertility sensor. For detecting concentration of combustible gases in air various types of sensors are available. Among them, semiconductor gas sensors are particularly interesting because of their structural simplicity and low price. But limitation of these sensors is their operation at elevated temperature (typically in the range 200-250 °C), so power requirement is high. Carbon nanotubes (CNT) has good electrical and chemical properties which are widely used. Gas absorption in CNT is an important factor for many applications.

Carbon nanotube change their electrical resistance when exposed to gases. These properties of Carbon Nanotube can be used to design a soil fertility sensor. Two types of carbon nanotubes either a single-walled carbon nanotubes (SWNT) or multi-walled carbon nanotube (MWNT), can be used to detect gases like ammonia, nitrogen etc. The proposed system uses a single-walled carbon nanotube to make soil fertility sensor. The carbon nanotube sensor was fabricated by deposition of SWNT on a silicon substrate between two parallel patterned electrodes. Positive and negative charge is stored at end of electrode. Carbon nanotube is exposed to environment. The sensor geometry is equivalent to large area transistor with effective channel width of 5mm.

The electrodes provide contacts for measurement of the conductance of CNT and substrate bias serve as a gate voltage that can be used to accumulate or deplete the network of charge. We have observed change in resistance when carbon nanotube sensor is exposed to soil. When soil contains ammonia (NH_3), the electrical resistance of the sensor increases. This phenomenon is depending on p-type semiconductor theory. When electron donation molecules e.g. NH_3 exposed to carbon nanotube sensor, charge carrier recombination will take place resulting in hole depletion. This causes decrease in conductance of CNT. When electrons withdrawing molecules e.g. Nitrogen (NO_2) interacts with carbon nanotube, hole concentration will increase so it causes increase in conductance. According to this principle when CNT is exposed to soil it will change its properties by absorbing organic molecules of soil and depending on it conductance will vary

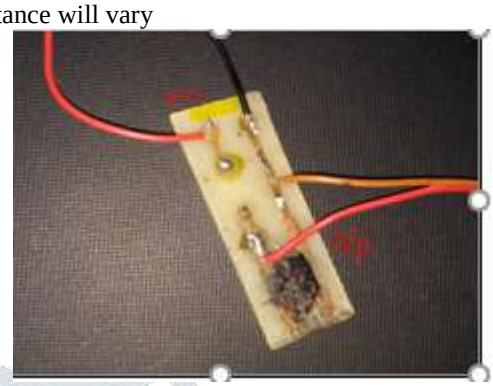


Fig.3.8 Soil sensor

3.2.4 DS18B20 Temperature Sensor

Soil temperature measurements were made through the digitalthermometer DS18B20. The DS18B20 Digital Temperature Probe provides 9 to 12-bit (configurable) temperature readings which indicate the temperature of the device. Information is sent to/from the DS18B20 over a 1-Wire interface, so that only one wire (and ground) needs to be connected from a central microprocessor to a DS18B20. Power f or reading, writing, and performing temperature conversions can be derived from the data line itself with no need for an external power sourceBecause each DS18B20 contains a unique silicon serial number, multiple DS 18B20s can exist on the same 1Wire bus. This allows for placing temperature e sensors in many different places. Its stainless-steel probe head makes it suitable for any wet or harsh environment.

Fig.3.9 DS18B20 Temperature Sensor

3.2.5 GSM Module:SIM900

The SIM900 is a complete Quad-band GSM/GPRS solution in a SMT module which can be embedded in the customer applications. GSM/GPRS TTL -Modem is built with SIMCOM Make SIM900 Quad-band GSM/GPRS engine, works on frequencies 850 MHz, 900 MHz, 1800 MHz and 1900 MHz. It is very compact in size and easy to use as plug in GSM Modem. The Modem is designed with 3V3/5V TTL interfacing circuitry, which allows you to directly interface to 5V microcontrollers as well as 3V3 Microcontroller. The baud

rate can be configurable from 9600-115200 through AT command. Initially Modem is in Autobaud mode. This GSM/GPRS TTL Modem is having internal TCP/IP stack to enable you to connect with internet via GPRS. It is suitable for SMS as well as DATA transfer application in M2M interface. The onboard Regulated Power supply allows you to connect wide range unregulated power supply Using this modem, you can make audio calls, SMS, Read SMS, attend the incoming calls and internet through simple AT commands.

Fig.3.10 GSM Module

3.2.6 Ultrasonic Sensor

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules include ultrasonic transmitters, receiver and control circuit**.** This sensor is a very popular sensor used in many applications where measuring distance or sensing objects are required.**HC-SR04 distance sensor** is commonly used with both microcontroller and microprocessor platforms like Arduino, ARM, PIC, Raspberry Pi etc. The Trigger and the Echo pins are both I/O pins and hence they can be connected to I/O pins of the microcontroller. To start the measurement, the trigger pin has to be made high for 10uS and then turned off. This action will trigger an ultrasonic wave at frequency of 40Hz from the transmitter and the receiver will wait for the wave to return. Once the wave is returned after it getting reflected by any object the Echo pin goes high for a particular amount of time which will be equal to the time taken for the wave to return back to the sensor. The amount of time during which the Echo pin stays high is measured by the MCU/MPU as it gives the information about the time taken for the wave to return back to the Sensor. Using this information, the distanceis measured. The proposed systemuses this principle to detect water level in the tank.

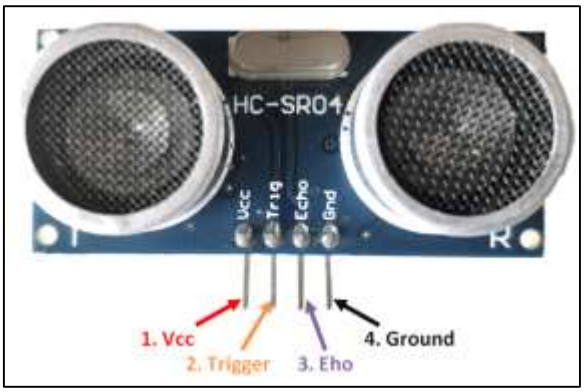


Fig.3.11 Ultrasonic Sensor

3.2.7 Relay

Relay is an electromagnetic device which is used to isolate two circuits electrically and connect them magnetically. They are very useful devices and allow one circuit to switch another one while they are completely separate. They are often used to interface an electronic circuit (working at a low voltage) to an electrical circuit which works at very high voltage. For example, a relay can make a 5V DC battery circuit to switch a 230V AC mains circuit. The proposed system uses relay to operate 12V solenoid valve and 230V pump motor.

Fig.3.13 Relay

3.2 Implementation

Flow chart:

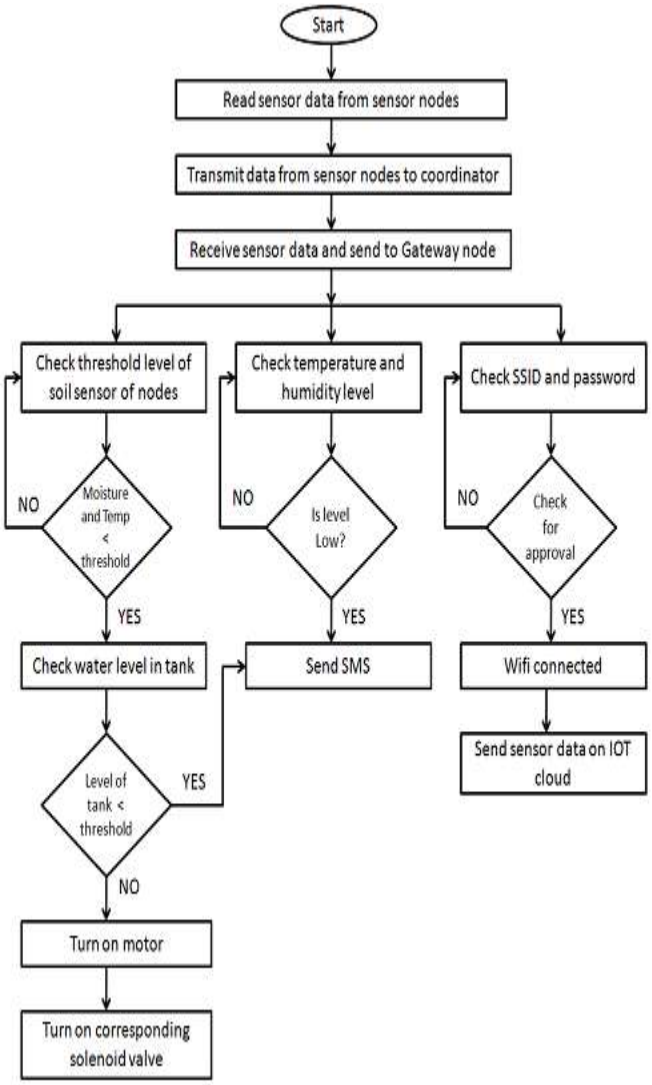


Fig.3.8 Flowchart of software implementation

Initially the sensor nodes and coordinator establish a wireless sensor network with the help of PANID assigned to zigbee modules. Whenever sensor node receives a polling signal from coordinator node data of serial monitor is transmitted via a Zigbee transceiver. At coordinator node data received from various sensor node is analyzed by NodeMCU. Each sensor values is compared with the reference values for each sensor node and if it is less than the reference value, then the irrigation process get started. Otherwise the system starts to collects the next periodical information. In case of water requirement, system first checks the water reservoir and then initiate signal to irrigate particular sensor node. remote monitoring of all sensor data is done by sending data to IoT thing Speak cloud by using ESP8266 Wi-Fi. For this wi-fi will first validate SSID and password before connecting to cloud. Also, Farmer will get indication for abnormal condition by using GSM module Fig .4 shows the flowchart of software implementation.

IV. RESULTS

In our country, most of the rural farmers rely on rainfall for their harvest; but the rainfall is non-uniform and irregular. This creates problem in irrigation which badly affects the agricultural output. The project is designed to develop an automatic irrigation system which switches the pump motor ON/OFF on sensing the fertility of the soil. In the field of agriculture, use of proper method of irrigation is important.

This project covers the application of sensor based irrigation system through wireless sensor networks which includes temperature and humidty and soil fertility sensor interfaced with node MCU. The advantage of using this method is to reduce human intervention and still ensure proper irrigation.

4.1 Interfacing of temperature sensor DHT11 with Node MCU

This project consists of an automatic irrigation system implemented with the help of Wi-Fi technology. DHT 11 sensor is used for humidity and temperature sensing Sensor is interfaced with Node MCU which includes firmware which runs on the ESP8266 Wi-Fi SoC and hardware which is based on the ESP-12 module. Interfacing is shown in Fig.4.1. Wiring the **DHT11** to the NodeMCU is really easy.Wiring connection is as follows.

Pin 1 of the DHT11 goes into **+3v** of the NodeMCU.

Pin 2 of the DHT11 goes into Digital Pin **D1** of the NodeMCU

Pin 3 is not connected

Pin 4 of the DHT11 goes into Ground Pin (**GND**) of the NodeMCU Software used for programming is Arduino IDE

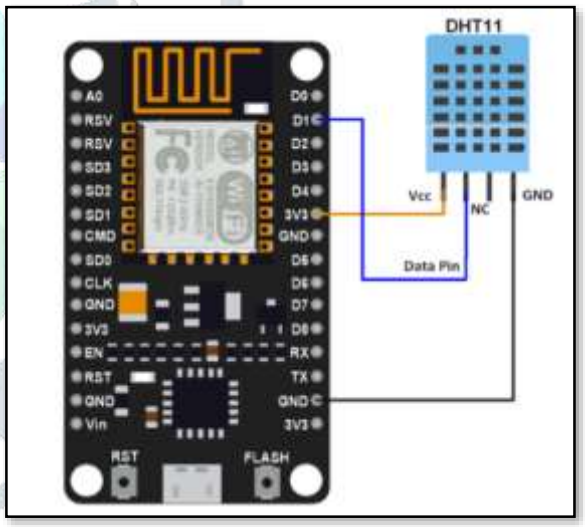


Fig. 4.1 Interfacing of DHT11 with Node MCU

Output on serial monitor of Arduino IDE is as follows

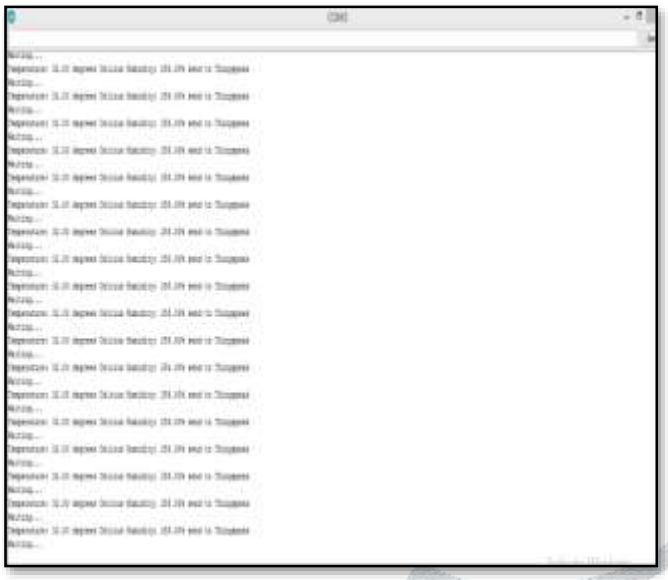


Fig.4.2 Output of DHT 11 sensor on serial monitor of Arduino IDE

4.2 IoT Based Remote Monitoring

Fig. 4.3(a) IoT Based Remote Monitoring

Thing Speak is an open source "Internet of Things" application and API to store and retrieve data from things using HTTP over the Internet or via a Local Area Network. Each Thing Speak Channel supports data entries of up to 8 data fields, latitude, longitude, elevation, and status. Thing speak was originally launched by ioBridge in 2010 as a service in support of IOT applications.

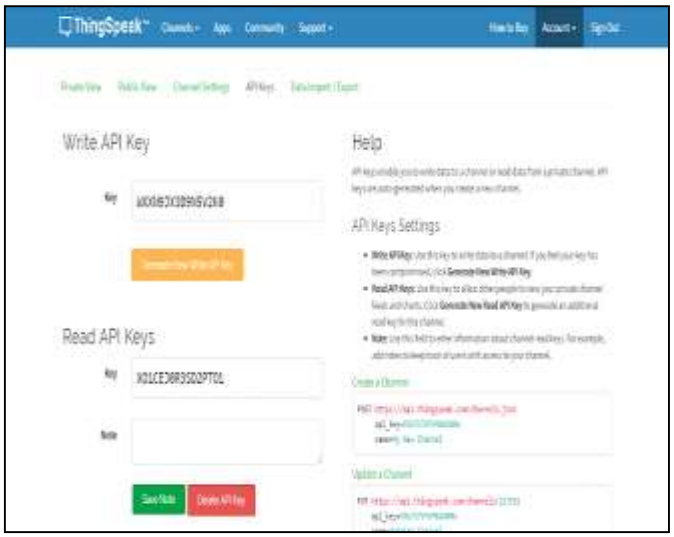


Fig. 4.3(b) Display of channel API keys to read from and write to the channel.

Thing speak is a platform providing various services exclusively targeted for building IoT applications. It offers the capabilities of real time data collection, visualising the collected data in the form of charts, ability to create plug-in and apps for collaborating with web services, social network and other APIs. To use Thing speak, the user needs to sign up and create a channel. Once a channel is created data can be sent allowing Thing speak to process it and retrieve the same. Output of DHT11 interfaced with Node MCU on thing speak is shown below.

Fig.4.3(c) Temperature and humidity data from DHT 11 sensor on Thing speak

4.4 Soil Fertility Sensor output

Fertility of soil is proportional to conductivity .Soil fertility sensor using carbon nanotube gives result as shown in table .From observation soil with moisture and fertilizer has good conductivity as compare to dry soil. Fertility also varies as per types of soil. Different types has different fertility level. From results red soil has more conductivity as compare to dry soil. This variation in fertility level will be useful for implementing automatic irrigation system.

Types of Soils	Volt	Conductivity
Dry- Red Soil	7.5V	Bad Conductivity
Wet- red Soil	3.2V	Very Good Conductivity
Red- Soil With Fertilizer	2.2V	Very Good Conductivity
Black–Soil with Fertilizer	2.5V	Very Good Conductivity
Dry- Black Soil	7V	Bad Conductivity
Wet-black soil	4V	Good conductivity

Table No.4.1 Output from soil fertility sensor

V. CONCLUSION AND FUTURE SCOPE

Intelligent sensors and wireless communication have become a standard procedure for measurement of process plant and environmental parameters. DHT11 sensor for temperature and humidity have been interfaced with a 32bit Node MCU, for processing and displaying parameter over IOT platform and communicating to the central node over 802.11b/g/n Wi-Fi channel. Also the soil sensor is designed and tested. As different plants grow on different types of soil which means the requirements are different. Thus the automatic water supply for the irrigation of the field can be achieved with the CNT based soil sensor by detecting different nutrient content of soil. Thus the system monitoring parameters along with the soil testing for fertility of soil in irrigation process will increase the yield of crops. It will also avoid the waste of water resources. This irrigation system will allow cultivation in places with water scarcity thereby improving sustainability. Using this system, one can save man power, water to improve production and ultimately increase profit.

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