WSN Hardware Prototype for Irrigation Control and Multi-Parameter Plant Growth Monitoring Using Iot

Ketan Joshi, Swapnil Jain, Ashish Patwari.

Abstract: The agriculture sector has always been a crucial factor in India's growth. It is utmost important to bring efficiency and precision in farming. This paper proposes the use of a Wireless Sensor Network (WSN) to develop an automated and intelligent irrigation system. The SENSEnuts embedded platform is used to create and maintain the WSN. The proposed system uses soil moisture data from different nodes which are deployed at various locations in the crop field. The nodes form a WSN. Each node (consisting of NXP JN5168, a 32-bit microcontroller) collects the data regarding the soil moisture and transmits it to the coordinating station (through Zigbee) which then takes the decision on whether or not to activate the sprinkler/motor pump. The decision is communicated to the corresponding node for further action. This enables precise watering only in the dry portion of the cultivation field and reduces the wastage of water or overwatering other moist areas. Apart from the soil moisture data, readings from the temperature, light, and humidity sensors are also transmitted to the coordinator. Such data is useful for indoor, underground or nursery crop monitoring. A working prototype of the proposed WSN is made and the functionality is verified. The data from various sensors is uploaded to the Thing Speak Internet of Things (IoT) platform for remote monitoring and further data analytics.

Keywords: Internet of Things (IoT), SENSEnuts, Soil moisture, Thing Speak, Wireless Sensor Network (WSN), Zigbee.

I. INTRODUCTION

Agriculture is a key sector to India's developing economy. India is a pioneer in this sector and exports products to many other countries. Agriculture not only provides food and fodder but also boosts other sectors like dairy, textile etc. Huge technological investment in this sector should be the priority to drive economic growth. The increasing global warming is the cause of erratic weather patterns and rainfall which effects the agriculture sector badly. The increasing population and over-exploitation of water along with reduced rainfall causes a burden of the water resources [1]. So, water is a resource that should be used in a sustainable way without affecting production. The conventional methods of irrigation involve a person to constantly check the progress of water down the field. This may sometimes lead to over or under watering of crops due to human error and may result in downgraded product quality and reduced yield. Farmers need to understand when and how much amount of water is needed for a specific crop. Most farmers have little or no knowledge of their farm and are unaware of the methods to improve the production of agricultural practices. All these conflicts make it necessary to think of new support systems for agriculture. The automated irrigation system saves water, increases efficiency and reduces management cost [2]. Environmental parameters play a vital role in plant growth. Luminosity is crucial for the photosynthesis process. The growth of ornamental crops is good when sufficient light is supplemented. Relative humidity is an important factor for photosynthesis as well as in maintaining the plant structure. Temperature plays a vital role in greenhouse environment [3]. By careful monitoring of these parameters, the farmer can take precautionary measures if required.

A. Existing Methods of Precision Agriculture

Authors in [4] proposed a similar system of Wireless Sensor Network (WSN) of soil moisture sensor but use Radio Frequency Identification (RFID) technology to identify each sensor node. Authors in [5] have proposed the use of ZigBee module to transmit sensor data to Programmable Interface Controller (PIC) microcontroller and the Global system for Mobile Communication (GSM) modem was used to update the farmer about the conditions of a field. Authors in [6] have used an Arduino module to realize each node and Raspberry Pi was used to receive data from the ZigBee module for further processing. By collecting multi-parameters data, the system was able to optimize plant growth condition by controlling the parameters including temperature, humidity, illumination and irrigation rate [7].

B. Proposed System

Our proposed system provides low-power operation compared to the above solutions. It also overcomes the drawback of using RFID as the SENSEnuts module uses the MAC addresses to provide node IDs to each sensor node. The SENSEnuts platform is suitable because it is specifically designed for sensor network applications while Raspberry Pi is not. Our system is compact and allows quick deployment in the field as the design cycles shrink.

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II. WSN SYSTEM ARCHITECTURE DESIGN

This section describes the architecture of the proposed system for precision agriculture using wireless sensor network. SENSEnuts is an advanced, affordable and compact WSN research platform. This embedded system platform is supported by a user-friendly graphical user interface (GUI) and integrated with sensor nodes to monitor as well as to program for various applications. This platform is useful for research and industrial applications.

A. Sensor Node Design

The proposed sensor node structure is similar to a stack arrangement as shown in Fig. 1. The bottommost part contains a battery which provides mechanical support to the structure. On top of the battery container is the radio module. It has a microcontroller and PCB antenna embedded on it. Sensor modules are present in the middle section above the radio module. An Extender module and USB gateway module are attached in the top section.

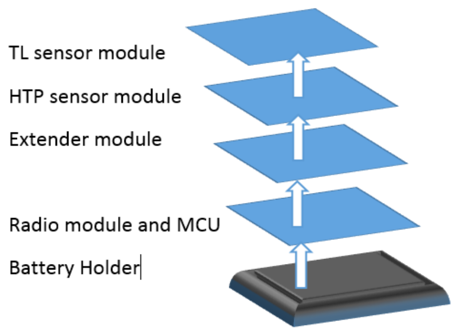

Fig. 1. Sensor Node/Coordinator

The details of each subsystem are given below. Fig. 2 shows the components at each node.

1. Radio Module*:* It has a microcontroller and a transceiver embedded onto a single PCB. The microcontroller present here is JN5168. It is an ultra-low power, high-performance wireless microcontroller. It works on voltage supply of 2V to 3.6V and has 32-bit RISC architecture. The Transceiver uses IEEE 802.15.4 networking stacks for transmission.

2. Extender Module**:** It extends all the pins of the microcontroller and makes it easier to connect external sensor and devices.

3. Humidity, Temperature and Pressure (HTP) sensor module**:** It has humidity, temperature and pressure sensors embedded on single PCB. Humidity sensor measures the relative humidity and provides a digital output with 14-bit resolution. Pressure sensor outputs barometric pressure with 24-bit resolution and temperature sensors output ambient temperature in degree Celsius.

4. Temperature and Light (TL) Sensor Module**:** It measures temperature and light intensity for environmental monitoring. The temperature values range from -25° C to 80° C with 12-bit resolution. Light ranges from 3-64k LUX with 16-bit resolution.

5. Soil Moisture Sensor**:** It is used to measure the moisture content inside the soil. Current is made to pass through two parallel probes of the sensor and then change in resistance is measured. These resistance values are inversely proportional to the soil moisture content.

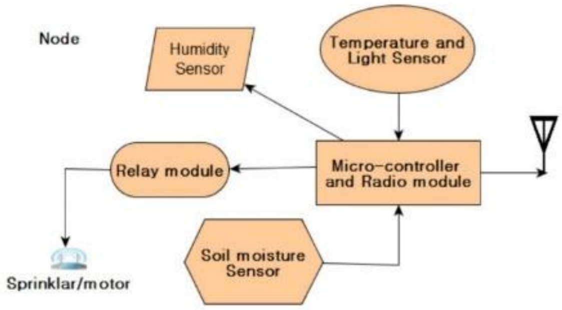

Fig. 2. Framework of Coordinator/Transmitting Section

B. Communication Standard

The wireless transmission of the data gathered by sensors from each node to the pan-coordinator is based on the IEEE 802.15.4 Zigbee protocol. Zigbee communication is widely used for wireless personal area networks and operates at a frequency of 2.4 GHz. It provides a data rate of 250 kbps and covers a range of 10-100 meters.

C. Receiving and Monitoring Unit

The pan-coordinator receives data from all coordinators and is connected to a personal computer (PC) as shown in Fig. 3 to enable the farmer present at the site to analyze and check the data coming from various sensor nodes. This section is responsible for bringing automation to the proposed system as it takes the decision and sends back a command to turn ON/OFF the water pump. If a farmer is staying at home and wants to check the real-time data, this unit has the provision to upload the data to the Thing Speak cloud which can be accessed from a mobile phone.

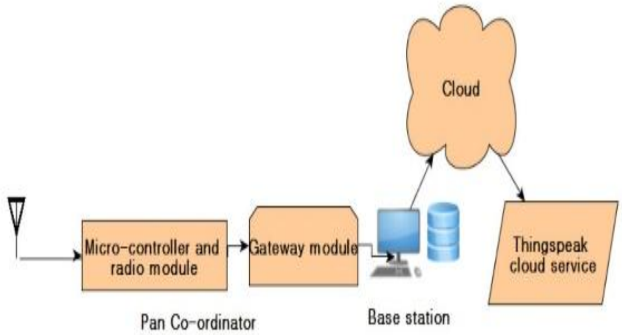

Fig. 3. Framework of Pan-Coordinator/Base Station

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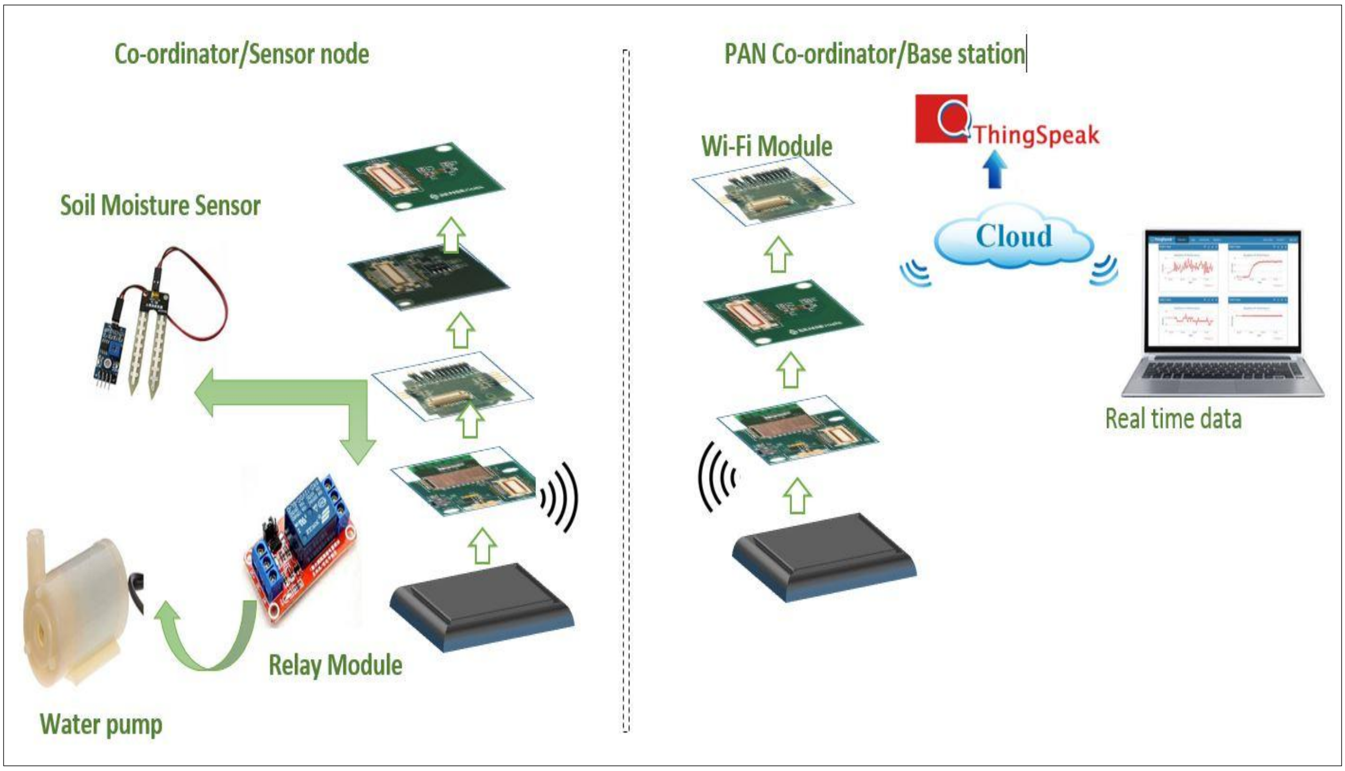

Fig. 4. System architecture for communication between individual node and base station

The pan-coordinator is also known as base station and comprises of following subsystems: -

1. PAN Coordinator: It is an intelligent device in the WSN architecture because it takes the decision based on the received values. It consists of an antenna and a micro-controller.

2. Wi-Fi Gateway Module: It is a low-power Wi-Fi networking module. It is also integrated with Serial Peripheral Interface (SPI) serial flash for software. It has a single band 2.4 GHz IEEE 802.11b/g/n 1x1 Wi-Fi transceiver.

III. WSN SYSTEM ARCHITECTURE IMPLEMENTATION

The main objective of this paper is to design an automated and intelligent system involving SENSEnuts WSN platform and Thing Speak Cloud service for remote monitoring which will bring a change in the currently used irrigation methods and helps farmers to obtain optimum yield from their crops. The system architecture is shown in Fig. 5 and the system operation is depicted in Fig. 6.

The workflow applies to each of the sensor node deployed in the field and the PAN coordinator associated with the network. This system is capable of sensing soil moisture value and can switch ON/OFF motor accordingly. Simultaneously it can monitor humidity level, light and temperature data. The field is divided into different regions according to the crops cultivated in that area. Sensor nodes will be deployed in that region such that no part of the field is left uncovered. Each node is programmed and the threshold value of soil moisture is set as per the requirement of the crop in that zone. These

3. Gateway Module*:* It programs the microcontroller and acts as an interface between the network and the PC. It has a data transfer rate is 115200 baud.

4. SENSEnuts Toolchain*:* It comprises of an intuitive GUI providing software support for the application. GUI is used to flash the code to the nodes and for viewing live data received from the network. The data is displayed and represented in the form of tables with a separate table to view the latest data from each node. The system architecture for communication between individual nodes and the base station is shown in Fig. 4 above.

SENSEnuts aided WSN uses the IEEE 802.15.4 (Zigbee) standard to communicate. Now, the PAN Coordinator (Intelligent device) will perform an energy scan. Out of the various channels available in the 2.4 GHz band, it will select the quietest channel (channel having minimum energy) and gets associated with that channel. Rest Coordinators (Sensor nodes) will perform an active scan. These coordinators will ping each channel and check whether the PAN Coordinator is associated with it. The process repeats until all the coordinator will find the PAN coordinator associated channel. Now, wireless sensor network (WSN) is established. This is a one-time process that is performed after the installation of the system.

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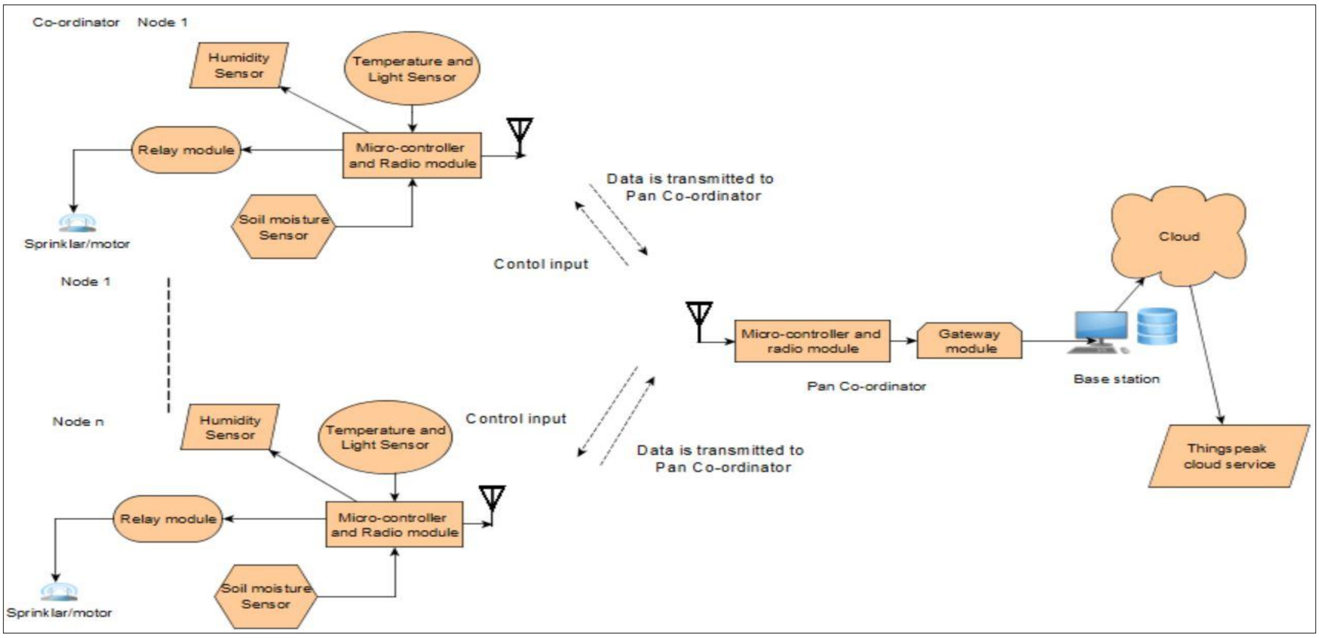

Fig. 5. Block diagram of proposed system

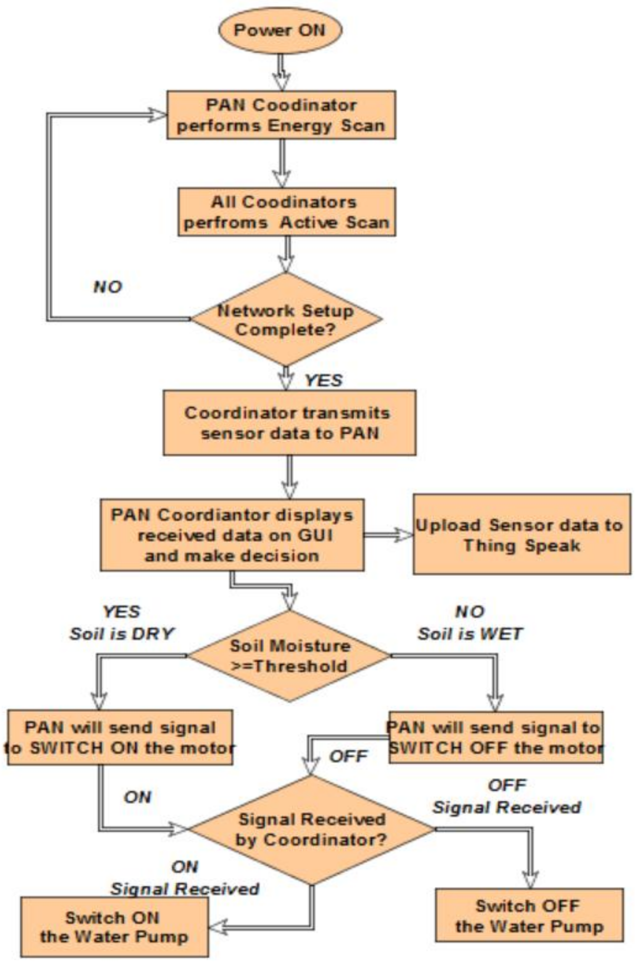

Fig.6. Flowchart of the proposed system

Basically, entire system functionality is subdivided into two parts

A. Controlling: PAN coordinator plays a key role in this part and is programmed such that it will take controlling action only on soil moisture data. PAN coordinator has the knowledge of the soil moisture threshold of sensor nodes in the different region. For example, if the field is divided into four different regions (A, B, C, and D) as per the crops cultivated in that region, it knows the threshold values of the sensor nodes in region A, B, C and D. Now, if the crop cultivated in the region A demands more water than all the regions, then the threshold value of soil moisture will be more in that region. Assuming that the soil is initially dry, the PAN coordinator will get to know about soil condition from the received data and sends a signal to the node (coordinator) to switch on the water pump. In turn, the coordinator activates the relay module to start the pump. Simultaneously, monitoring of soil moisture is happening by soil moisture sensor and the coordinator will continue to transmit soil moisture values to PAN coordinator. Soil moisture will be increasing as the water pump is ON. At one point of time, soil moisture will reach the threshold value. In this situation, the PAN coordinator will sense the condition and send the signal to the coordinator to switch OFF the motor pump and continues to monitor all the parameters. Coordinator deactivates the relay module to stop the pump. In a similar way, the readings from other regions of the crop field such as B, C and D will also be processed by the pan-coordinator. It should be remembered that different regions of the cultivation field have been planted with different types of crops which require different levels of irrigation and water content. Therefore, the decentralization of the control to water the crops by forming a WSN where each node can take care of a particular region. Hence, the proposed system can cater to the problem of excess watering as well as precise irrigation for particular crops.

B. Monitoring: Sensors connected to coordinators play a vital role in this part. Soil moisture sensor will sense moisture content of the soil. HTP Sensor module will read humidity level and temperature values. Similarly, TL sensor module will be passing light data. All these sensors work simultaneously and 24x7 to monitor the parameters. Radio module (part of Coordinator) will transmit this data to the PAN Coordinator. PAN coordinator along with Wi-Fi module, connected PC forms a base station. PAN coordinator will receive the data and it can be displayed on SENSEnuts GUI. Wi-Fi module can be used to upload this data to the Thing Speak cloud platform. So, a farmer sitting at home can monitor these parameters using Thing Speak channel. In this way remote monitoring is possible.

IV. RESULTS AND DISCUSSION

The performance of the proposed WSN was tested for different soil moisture values. The experiment of real-time monitoring of various environmental parameters such as temperature, light, and humidity is conducted. The desired functionality of our proposed system in different condition is discussed next. Basically, the functionality of the entire system is subdivided into two parts.

A. Controlling: Based on predetermined soil moisture threshold, the PAN Coordinator will send a control signal to the coordinator to switch ON/OFF the motor pump as shown in Fig. 7 and Fig. 8.

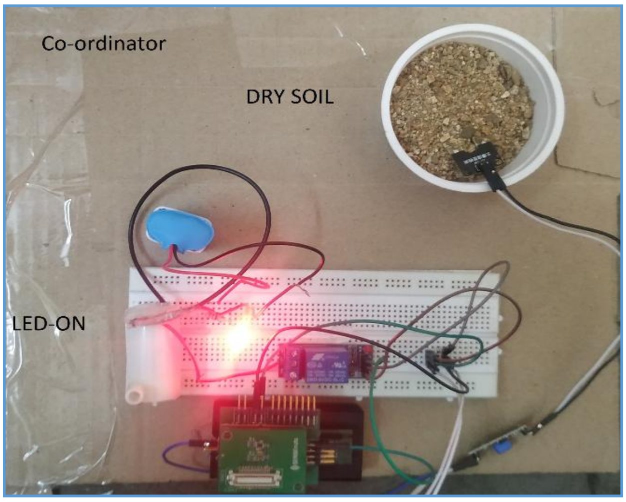

Fig.7. Soil moisture value above threshold. Motor is ON (LED is ON)

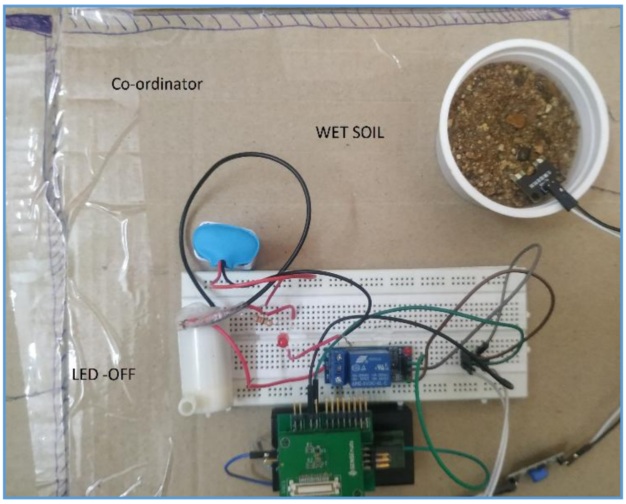

Fig. 8. Soil moisture value below threshold, motor is OFF (LED is OFF)

One node has wet soil whereas the remaining two had dry soil. So, the water pumps connected to the coordinators consisting of dry soil switch ON (LED is ON) and the Pump associated with wet soil remains OFF (LED is OFF). This can be clearly observed in Fig. 9.

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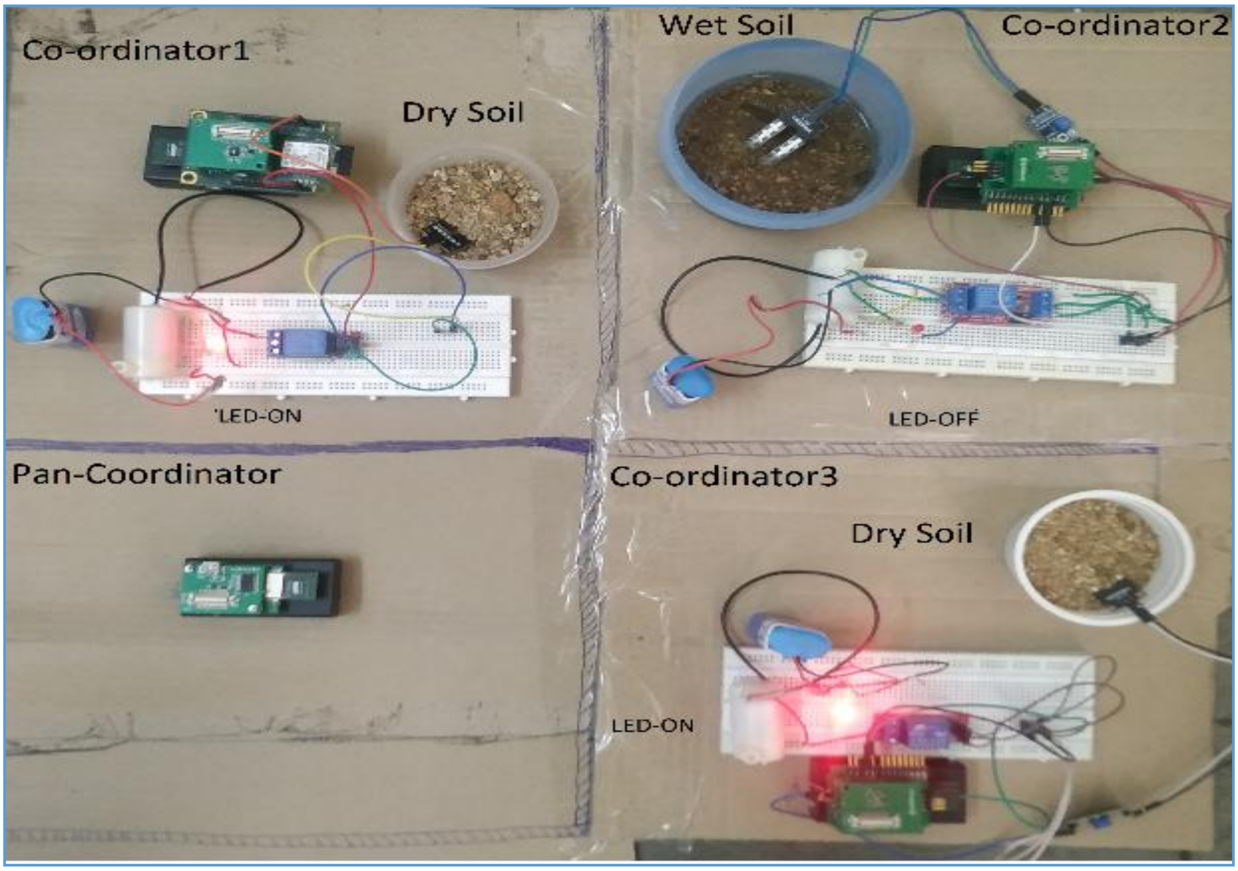

Fig. 9. LED connected to only one coordinator /Sensor node is OFF and rest all LEDs are ON

B. Monitoring: PAN Coordinator also monitors the environmental parameters (Humidity, Light and Temperature) by receiving data from individual coordinators. These values can be displayed on SENSEnuts GUI as shown in Fig. 10 and Fig.11.

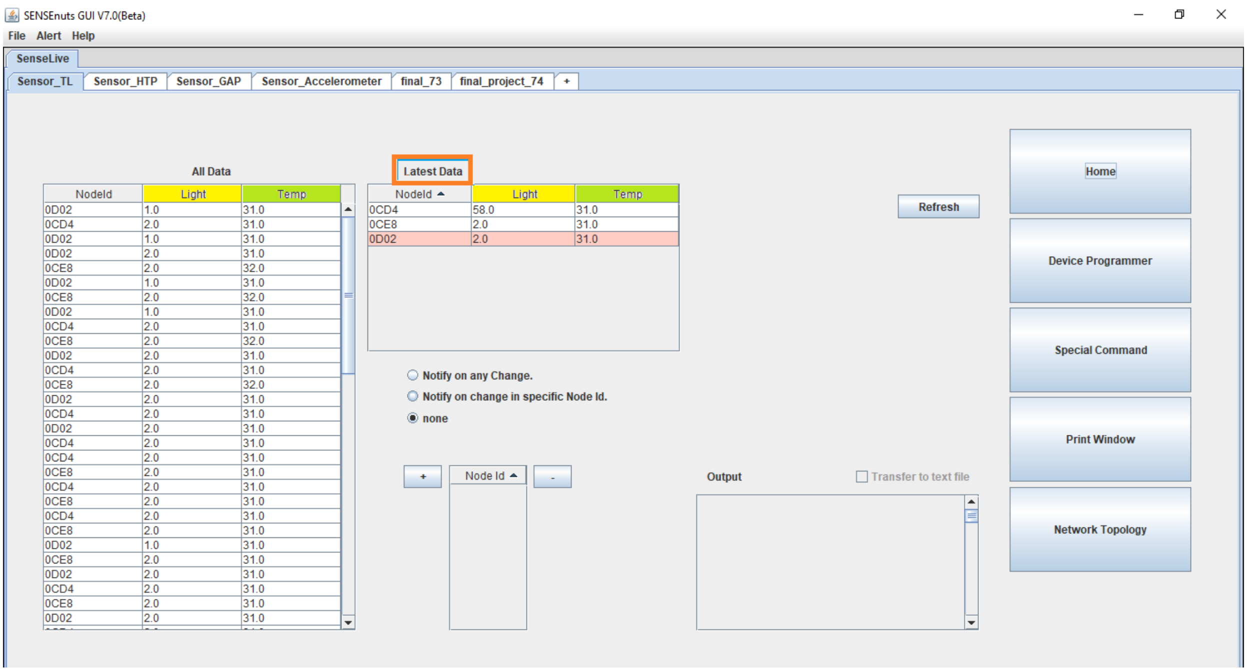

Fig 10. Temperature (highlighted as Green) and Light (highlighted as yellow) data from various sensor nodes/Coordinator

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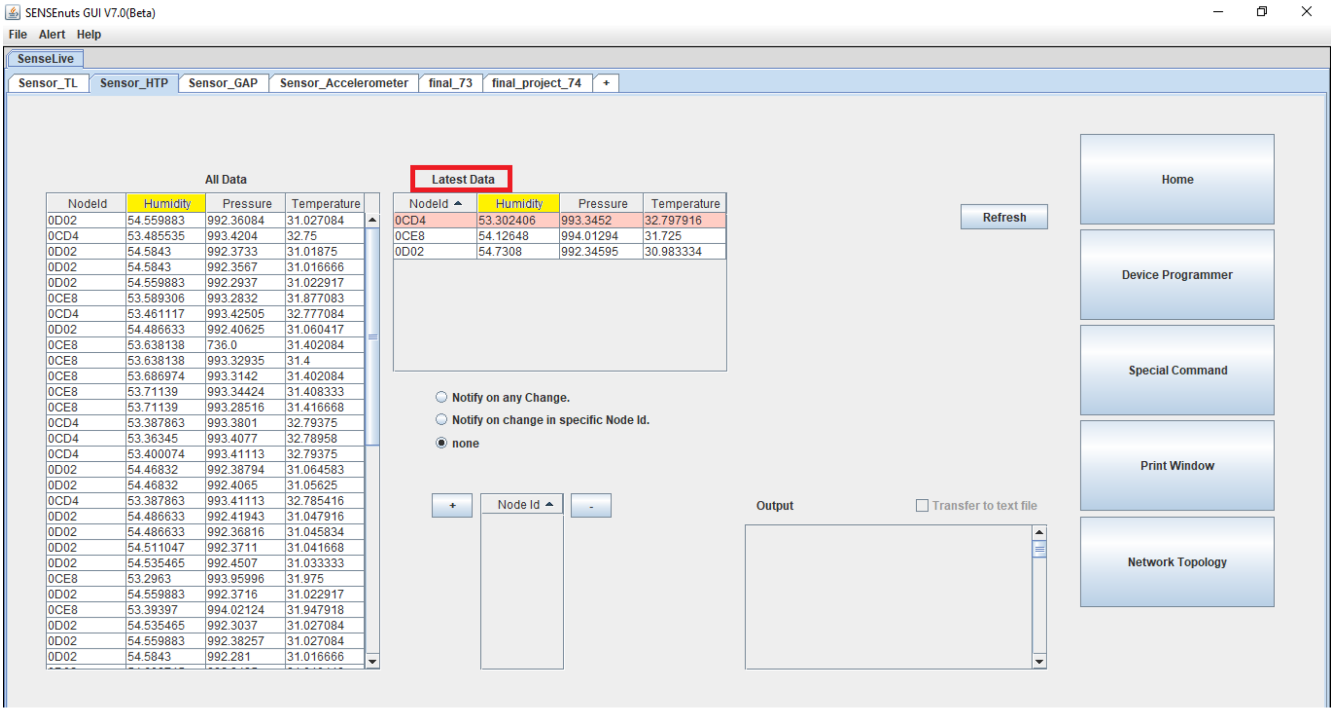

Fig. 11. Humidity values from various Sensor nodes/ Coordinators (highlighted as yellow)

Remote Monitoring: Internet of Things (IoT) plays key role in remote monitoring of above data. With the availability of internet, these parameters can be monitored from any place. Fluctuations in light intensity data can be observed in Fig. 12.

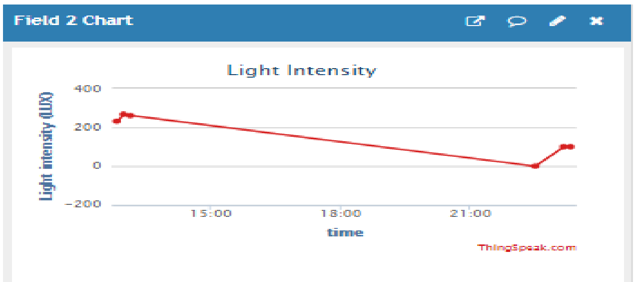

Fig. 12. Graphical representation of Light data

Similar graphical representation can be obtained for humidity and temperature also.

V. CONCLUSION AND FUTURE SCOPE

A fully operational working model of the proposed WSN for crop monitoring and precision agriculture has been designed and implemented using the SENSEnuts platform. It is found that the proposed system satisfies the various functional and non-functional requirements. The irrigation control is better as the crop field is divided into smaller regions, each served by a separate node where each region is served by a separate node, the irrigation becomes well controlled. It helps to limit the watering only to the regions where the soil is dry as each node is equipped with its own sensors and actuators. The compactness of the sensors and other modules make the handling quite easy. Additionally, since the data from various sensors is uploaded in the Thing Speak platform, further analysis could be performed to monitor the environmental and climatic patterns for plant growth. The system can be deployed in real scenarios to achieve efficient cultivation.

The proposed method offers lot of future scope as mentioned below. As discussed in [8], the WSN can be used to detect various nutrients level in the soil specific to a particular crop. As discussed in [9], the camera module and MATLAB available with SENSEnuts can be used to perform image processing on the crops to recognize weeds. Other improvements such as the usage of solar energy to power the system can be adopted. Global Positioning System (GPS), Accelerometer & PIR (GAP) sensor is used to extract the GPS coordinates which can be used for satellite imaging of the field.

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