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MQTT Protocol based Smart Greenhouse Environment Monitoring System using Machine Learning

G. Sai Teja, P. Sathish.

Abstract: Internet of Things (IoT) allows connections among various devices using the internet with the ability to gather and exchange data. IoT has various connecting protocols like HTTPS, MQTT, CoAP, SMCP, etc. A lightweight protocol of all these protocols is the Message Queuing Telemetry Transport (MQTT) protocol. Agriculture is the backbone of India it plays a significant role in the growth of the economics of the country. The majority of the population in India focused on developing a good yield of the crop at their available space which is leading to the development of various greenhouse and smart farming methods. The technology developments will be enabling to design and develop a simple intelligent system for smart farming and maintaining the greenhouse environment. The proposed system is designed using an ARM Cortex processor with the other supporting peripherals for monitoring and constantly updating and controlling environmental parameter values to achieve optimal growth and yield of plants. In this paper, the proposed system consists of several sensors for measuring different parameters including temperature, humidity, soil moisture, air pressure, and fertilizer content. Further, the obtained data is sent to the cloud by using IoT based ThingSpeak with the secured MQTT protocol to monitor the parameters. An efficient Machine Learning algorithm is developed to predict the parameters like soil moisture, fertilizer content sprayed and weather data i.e., humidity, and temperature. The accuracy obtained using Machine Learning algorithm i.e. Decision Tree method is 97%.

Index Terms: Machine Learning, MQTT, IoT, ARM, ThingSpeak.

I. INTRODUCTION

Among all the sectors, there is rapid growth in the agriculture sector. The increase in the farming sector is due to the introduction of a smart agriculture concept using IoT devices, digitalization, and greenhouse. The term greenhouses mean a controlled environment space or area to grow plants [1]. To increase the yield production of the crops different environmental parameters including temperature, air pressure, humidity, soil moisture, fertilizer content in the farm, etc. needs continuous surveillance and control are necessary for a greenhouse system.

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* Correspondence Author
G. Sai Teja*, Department of Electronics and Communication, CBIT, Hyderabad, INDIA. (e-mail: gandlasaitej@gmail.com).
P. Sathish Department of Electronics and Communication, CBIT, Hyderabad, INDIA. (e-mail: psathish_ece@cbit.ac.in).

Even the population in the world is growing day by day so the need of food and limitation of space or land as an agro-economic activity make smart farming and greenhouses are becoming popular and has become one of promising solution for securing the food supply. Apart from that, extreme weather changes and climates affect the production of the crop, thus increasing their prices and lowering the quality of the crops produced [9]. The Internet of Things allows for clear linkages between various computers, apps, and internet infrastructure, and this system often enables people to operate easily. As claimed by the government of INDIA the IoT policy, the government plans to invest 15 billion in the IoT domain by the year 2020. Besides, in the Indian Government's policy, IoT helps automate solutions to the problems facing different industries, such as shopping, disaster management, farming, vehicles, mining, banking, and so on. There is a huge and wide range of IoT equipment designed by various organizations are market available for services such as quality of water monitoring, crop growth patterns tracking, smart routes for field sprinkling pesticides and fertilizers, high-tech laser-assisted precision land leveling, plants, and human health monitoring, and various other applications. But most sections available in the market are inexpensive and the procurement of this commodity is economically unnecessary in a nation such as India still has low and marginal 80% of farmers [7].

II. LITERATURE SURVEY

Hamza, Mounir, Khaoula, designed a smart irrigation system based on Arduino and ThingSpeak for Algeria. The system is based on the IoT platform ThingSpeak cloud and Arduino to control the irrigation by using smartphones. The authors used the ESP8266 Wi-Fi module to communicate with the cloud and the sensors networks. Few gaps observed in the like in this system there is no SMS alert related to the farmer. They did not measure the air temperature and air pressure of the farm. Any prediction methods are used by the authors in their design [1]. The authors developed an IoT based greenhouse model for traceability and monitoring of seedlings and other agricultural products in the germination and growth stages of a crop. The crop they used for the greenhouse system is the cherry tomato. The proposed method helps to monitor variables include luminosity, humidity, temperature, and use of water, showing the cumulative utilization of water by field, field trends, and time for production.

The system also enables automated control of the greenhouse using a temperature control or irrigation system and discusses the important profile of the in-home terrace of agricultural products ranging from seed to crop final produce.

They have done a novel behavioral study of many species comprising local agriculture. The data collected is uploaded to the web service platform and then shared with consumers and supply-chain actors. They used the Raspberry Pi 3 as the main microcontroller unit to communicate via Wi-Fi. Analog proportional-integral (PID) control techniques are being developed in conjunction with the multi-input Multi-output (MIMO) system. So, based on this assumption, a fuzzy PID control was constructed from a state-space in which all variables that make up the device have an influence. One of the gaps observed is that PID control is designed only for the temperature and humidity parameters [2].

Ravi Kishore Kodali et.al made an MQTT based smart irrigation system. The microcontroller unit used is NodeMCU and a soil moisture sensor, and with a water pump to pump the water. In this device Message Queue, Telemetry Transport Protocol (MQTT) is used for moving the records among NodeMCU12E and the sensor. Soil moisture sends data to NodeMCU-12E, if the soil is dry then NodeMCU-12E send instruction to the water pump and water pump will start and after moisture goes up by some value it will off the water pump. They are even using LCD to display the current state of soil and water pump. Depending on the reputation of soil moisture content material the control unit will power the pump-action of water and the same values are displayed on a web page of a browser or cell application. They used a thinger.io platform to display the value of soil moisture and relay position on a mobile app and web page. The security of the system is provided through cryptographic protocols Transport Layer Security (TLS) and Secure Socket Layer (SSL). The major gap of the system is the authors used NodeMCU microcontroller for the system development which can't be manufactured at the industrial level because it is too sensitive MCU. The proposed system is not using an algorithm to decide the status factors of the parameters [3].

The authors compared CoAP with MQTT in the smart health care system. They explained the importance of IoT in health and provided a summary of some clever health systems in addition to a summary of most of the application protocols used by listing their strengths and weaknesses [6].

III. MEASUREMENT PARAMETERS OF SMART FARM SYSTEM

Basically, many parameters are needed to be measured for the farm. However, the Smart Farm system proposed measures the key agriculture parameters:

- The temperature of the field atmosphere.
- Soil Moisture Level of the field.
- Fertilizer content sprayed on the farm.
- The humidity of the farm atmosphere.
- Air Pressure of the farm.

IV. METHODOLOGY OF THE PROPOSED SYSTEM

The Smart Farm/Greenhouse system makes use of four sensors (soil moisture, gas, pressure, and DHT-11), with a processing module Raspberry Pi with ARM microcontroller unit and one data transmission which is built in it. The main purpose of the proposed system is to gather sensor data and submitting it to the user every time a smart farm/greenhouse user wishes to verify soil moisture, fertilizer content, and temperature, humidity, and pressure. The Raspberry Pi acts as an Internet access portal server. It functions as a mini-network with sensor control. The data is protected by security (secure socket layer) protocol. Also, the MQTT Server stores data on an ongoing basis. The benefit of using the cryptographic MQTT protocol and Transport Layer Security (TLS) is that no uncertain data is saved along with the correct data. All the data of sensors processed by the MCU and updated into the ThingSpeak server. The entire block diagram of the designed system is shown in figure 1.

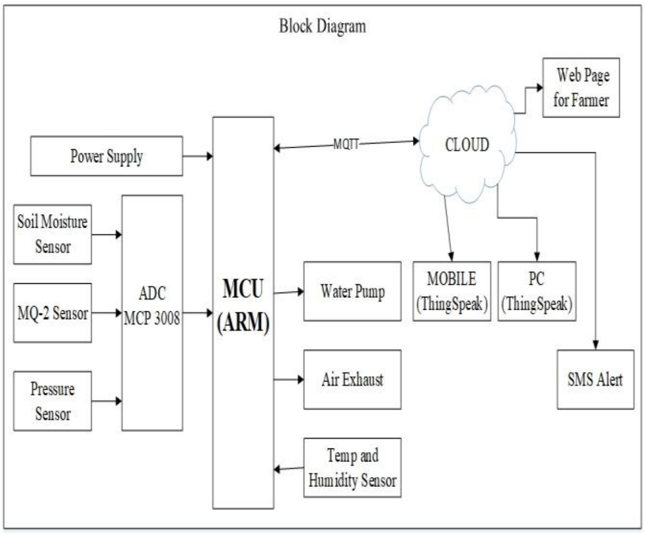

Fig. 1. Block Diagram of the System

The authorized users can access this data using a User ID and password to log into their accounts to view data on the ThingSpeak server. The parameters are also displayed on the customized website for the farmers. Form that website not only the farmer can see the parameters of the farm but also control the farm by ON/OFF of the eater motor or ON/OFF the fan if needed even when it is automated. The information all will be stored, distributed, interpreted, evaluated, and displayed in real-time. The monitored data is stored in the database for further data processing. Here the user will also get an SMS alert if there is any change in the parameters of the farm. The collected data is verified, processed, and sent for machine learning algorithm for prediction purposes. Here the farmer is provided with an algorithm outputs so that the accuracy of the parameters is improved. A decision tree algorithm is used. The parameters like the temperature, humidity, air pressure, soil moisture, and the fertilizers sprayed will be predicted by the algorithm.

A. Raspberry Pi 4

The Raspberry Pi is a microcomputer with debit card thickness. This has the power to process code for programming and to monitor a large range of components using its GPIO pins, the complete smart farm monitor network.

With a 64-bit ARMv8 Quad-Core processor with a 1.5 GHz minimum, the Raspberry Pi is equipped with BCM2711. This features 40 GPIO connectors, 4 USB ports, two micro HDMI sockets, and the micro-SD slot. [12]. The Raspberry Pi provides wireless networking through Wi-Fi and Bluetooth devices.

The Raspberry Pi can be configured until the computer is attached to a display, mouse, and keyboard. Raspberry Pi can be linked and managed via Secure Shell (SSH) from a smartphone or device. Putty is a Windows SSH free client [13] which is used in this system, developed by Simon Tatham. In short, the Raspberry Pi connected to various sensors, using Python codes and performing properly specified codes with the correct commands. Raspberry Pi 4's front plot is seen in figure 2.

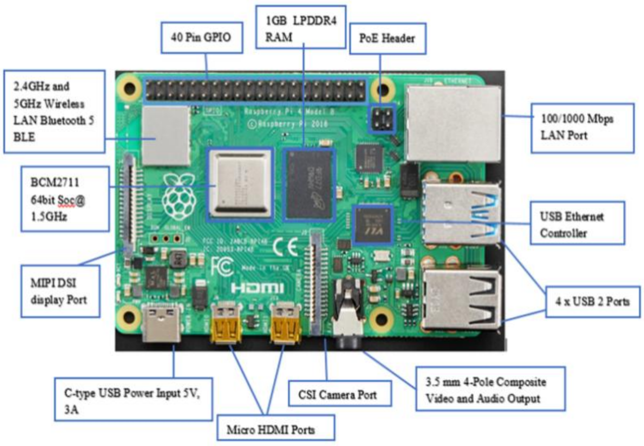

Fig. 2. Raspberry Pi 4.

B. Sensors

The various sensors used in this work are explained in the following section.

1) Soil Moisture Sensor (FC-28)

The sensor of ground moisture uses the soil determining the volumetric water content. The relationship between the property measured and the ground moisture must be modified, depending on environmental conditions such as temperature, soil content, and other electrical conductivity [1]. The microwave emissions reflected can be affected by soil moisture and are primarily used for agriculture and remote hydrological sensing. Such detectors are generally called gypsum blocks as soil water-potential detector. Its device can be worked by placing it in the earth and recording the status of the amount of water in the soil as shown in figure 3.

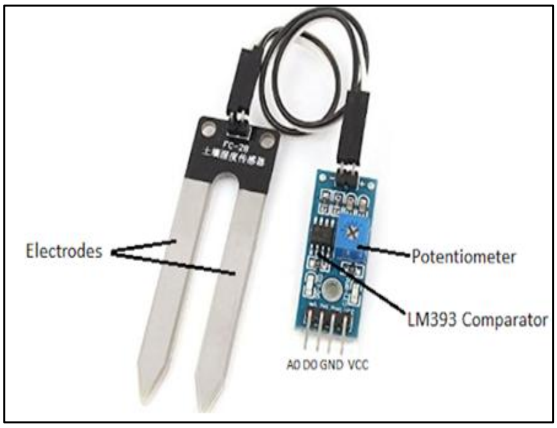

Fig. 3. Soil Moisture Sensor

2) Gas Sensor (MQ-2)

It is a metal oxide semiconductor (MOS)-style Gas Sensor as shown in figure 4, which is often referred to as chemical resistors since the sensing device is based on resistance changes as the gas interacts in the device. Gas concentrations can be measured using a simple voltage splitter network. It detects gasses such as LPG, alcohol, propane, carbon, CO, and even methane and can be measured [14]. The sensor's module version is supplied with a wireless pin to work without a microcontroller. The analog pin must also use the analog pin in ppm when measuring the gas.

Fig. 4. **Gas Sensor (MQ-2).**

3) Temperature and Humidity Sensor (DHT-11)

The DHT11 commonly used for the measurement of surrounding atmosphere temperature and humidity values as shown in figure 5. The sensor comes with a Negative coefficient of temperature to calculate the temperature and has an 8-bit microcontroller to output, so that the temperature and moisture values are transmitted as serial data. to the microcontroller. The sensor is also factory calibrated so we need not calibrate it again and hence easy to interface with other microcontrollers [7]. This sensor is used to find the surrounding atmosphere temperature so that the pH sensor and turbidity sensors work correctly for a long duration of time. The type of marine species that can live in the water can also be determined by temperature calculation.

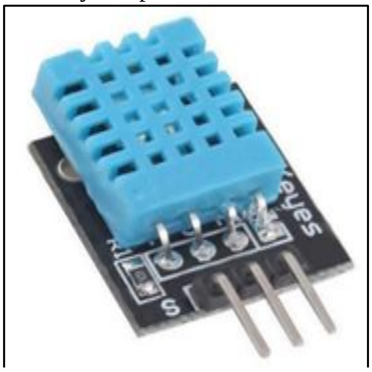

Fig. 5. DHT 11 Sensor

4) Piezoelectric Transducer

A piezoelectric transducer as shown in figure 6 is a measuring instrument that translates energy into electrical charge for measuring the speed, strain, stress, and energy [16]. Its principle is that the power produces electric charges on the crystal surface when applied to the quartz crystal. In the same way, a force or acceleration can be measured, the Piezoelectric Transducer can calculate pressure [15]. Possible volume vibration should be accounted for low-pressure calculation.

Fig. 6. Piezoelectric Transducer

5) Relay

Relays are the most commonly used switching device in electronics [16]. It is a device that is operated electrically. It detects the undesirable condition in a given region and controls the breaker circuit for the field being disconnected by ON or OFF. Relay has 3 main pins they are Common pin (COM), Normally Open (NO), Normally close(NC). If the circuit of relay senses the current fault, the electromagnetic area that creates the temporary magnetic field is energized. The magnet effect drives the armature of the relay for the connections opening or closing up.

6) Water Pump

Micro water pump 3-6V Mini submersible pump is used in this system design. It is a low-cost, lightweight Submersible pumping motor that can be operated from 3 ~ 6V. With a low current consumption of 220 mA, it takes up to 120 liters an hour. The pipe of tube is simply attached to the motor outlet, submerged, and operated in water [1]. The dry run may cause heating damage to the motor, and it will also cause noise.

7) DC Fan

With a scale of 40x40 mm, the Brushless DC Cooling Fan works at 12V.The fan is extremely quiet and pushes around 20CFM [7]. It is used in the system to cool the farm when it is used as a greenhouse product to control the humidity and temperature of the house for the farmer.

C. Python

Python is an immensely common scripting language [17] because of its flexibility to code the large array of functions customized to all the user's needs. Python is used for the creation of a program that integrates the sensors and target board.

D. ThingSpeak Server

ThingSpeak is an IoT data collection application for the analysis of various sensors, e.g. temperature, soil moisture, humidity, pressure, fertilizer content sprayed etc. The data collector collects data from edge node devices (this happens with the Raspberry Pi) and also allows the data to be modified for historical data analysis in a software environment using secured MQTT protocol. First, the user must log in with details on his / her server. The key component of ThingSpeak operations is the channel containing data fields and a status screen. After a ThingSpeak channel has been developed, data is modified, processed, and interpreted with MATLAB code, and the data is reacted by tweets and other alerts [18].

E. MQTT Protocol

MQTT is an application layer interface that utilizes the network TCP / IP type of communication. It is a protocol suited for devices with minimal resource requirements and was invented in 1999, Arlen Nipper and Dr. Andy Stanford-Clarke. The protocol is lightweight, transparent, simple to use, and suitable for connectivity in environments such as IoT of resource management [4]. MQTT is designed to ensure reliable message delivery for resource-rest rusted devices in restricted environments such as low network bandwidth and unsatisfactory networks. The message is transmitted using the publish-subscribe message protocol client-server. This protocol has Clients subscribe to topics called SUBSCRIBE. Messages shall be published in a PUBLISH subject name. The message routing is handled by a broker server. An address known as a topic is published in each message. Multiple topics can be subscribed to by clients. Each customer subscribed to a subject receives each message on the subject.

F. Machine Learning

Machine learning (ML) is about extracting knowledge from data. It is a tool for transforming information into knowledge. Machine Learning is simply defined as an automating and improving the learning process of their experiences are focused on computers without really being programmed, that means without any human assistance [19].

In this smart farming system mainly used supervised machine learning algorithm to predict the parameters and accuracy of the prediction. The algorithm in supervised learning is decision tree algorithm.

V. ALGORITHM OF THE SYSTEM

The proposed system's entire algorithm is shown in Figure 7. Initially, the installation of operating system and the required packages in Raspberry Pi are installed. Next for the python algorithm for the hardware configuration, the required libraries such as paho-mqtt, twilio, DHT-11 libraries and etc. are imported. As Raspberry Pi works in both BCM and board modes, in the hardware connection side the required mode need to be selected in the python code. Now the hardware pins of sensors which are connected with Raspberry Pi needs to be configured and declared. When the user initiates the code the sensors will be supplied with sufficient voltage and the data collection will be initiated by the target board. The collected data is transmitted via MQTT protocol to ThingSpeak server for data display for the farmer and analysis of the data. Even the same data is posted on the web site designed for farmers using PHP.

The hardware part of the system contains automatic motor ON/OFF and Fan ON/OFF for greenhouse to regulate greenhouse temperature and humidity. If the soil moisture is less than 40% automatically the water pump will be activated and about the same information of the motor status is sent to farmer as an offline SMS to his/her personal mobile. Even in case of temperature say for a particular crop if the green house temperature should not be more than 30 ^{0}C the automatically the exhaust fan will be activated to reduce the greenhouse atmosphere temperature. Even here the farmer will be getting an offline SMS to his/her personal mobile. The collected data is also further processed and given as the dataset for decision tree algorithm. The algorithm is trained with the real time data set and the parameters are predicted.

As well as the accuracy of the algorithm is also generated.

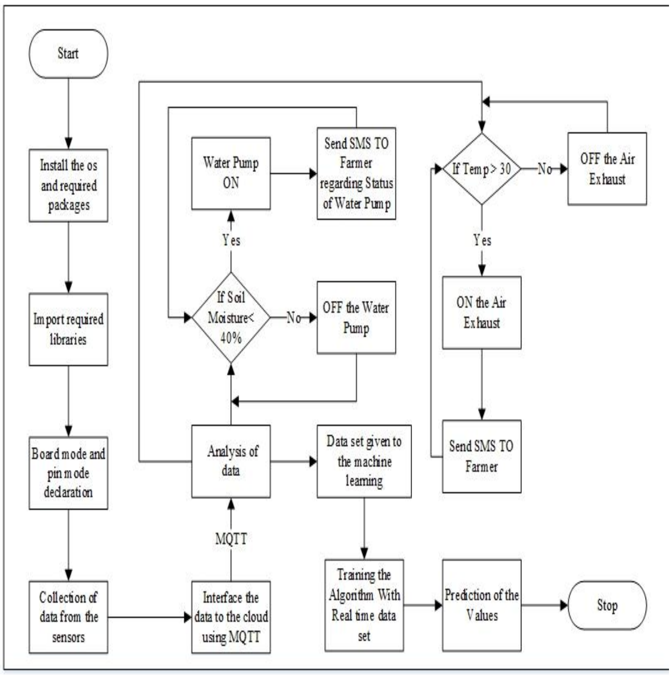

Fig. 7. Overall Algorithm for the proposed system.

The decision tree algorithm is a means of supporting decisions that have a map or decision-making models like a tree with chance results, resource costs, and utility. A decision tree is a structure that measures a particular attribute of each node, each branch is the outcome and each node is a class label as shown in figure 8.

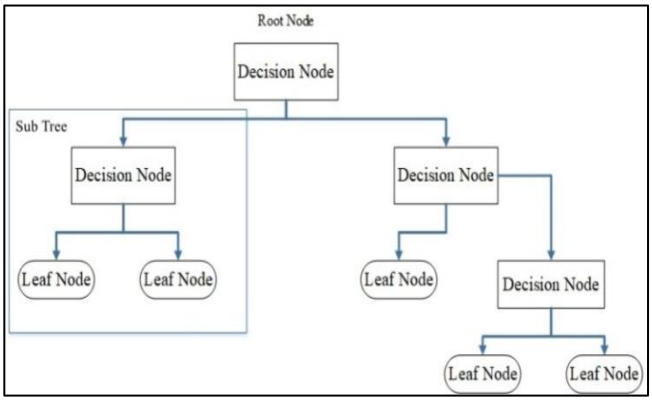

Fig. 8. Decision Tree Algorithm

The algorithm steps are as follows:

Step 1: Start the root node tree, says S that contains the entire dataset.

Step 2: Use Attribute Selection Measure (ASM) to find the best attribute in the dataset.

Step 3: Divide the S into subsets containing the best attributes possible values.

Step 4: Build the node for the tree, with the highest attribute.

Step 5: A set of latest decision trees are recurrently being made using the data set sub-sets generated in step 3. Continue until a step has been achieved in which nodes are not further classified and the final node is called a leaf node.

VI. RESULTS AND DISCUSSION

The experimental setup consists of an MCU with a sensor network that takes samples for every 10s from the smart farm/greenhouse and the parameters are displayed on the Python IDE terminal. For the real-time monitoring, the MCU unit also updates the ThingSpeak server forever 13s with different parameters. As well as the customized designed PHP webpage for the farmers will be updated. The entire hardware setup system is shown in Figure 9 and figure 10 with laptop.

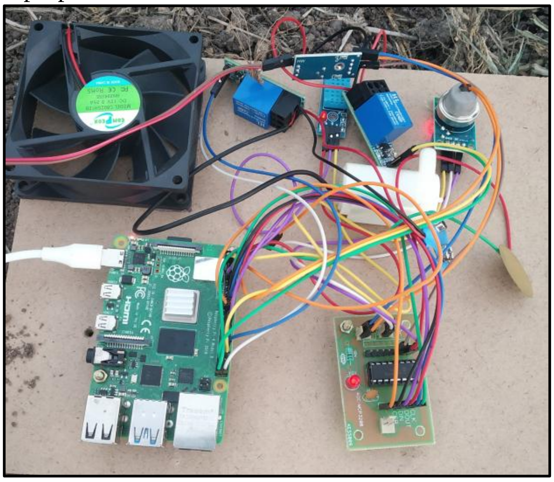

Fig. 9. Hardware Setup of Smart Farm/Greenhouse System.

Fig. 10. Hardware Smart Farm/Green House System in Farm.

A. Temperature and Humidity Sensor Results

Initially, the surrounding environment parameters like temperature and humidity calculated using the DHT-11 sensor module and updating it into the ThingSpeak Server as shown in Figure 11. In field 1 the temperature value updates whereas in field 2 the humidity value of the atmosphere is being updated respectively.

Temperature measured in degree C, and humidity measured in percentage. The temperature of the surrounding calculated because the for a particular farm in greenhouse a particular temperature is need to be maintained.

Not only in greenhouse even to grow a crop with a good yield the maximum temperature is needed. Mineral food, growth in the shoots and pollen development, resulting in low yields, are adversely affected by higher temperatures. Most crops can be destroyed every year by temperature above 50 ° C [20].

For instance, for rice crop to produce a good yield the critical temperature it can have up to 33°C, for sorghum 34°C, for finger millet 35°C, for pigeon pea 35°C and so on [21]. In figure 12, consider the temperature value at the time instance of 18:25hrs is 24°C and from field 2 at the same instance of time is 69% humid. But in the same graph at 18:40hrs the temperature raised to 25°C and at that same interval the humidity of atmosphere is gradually getting reduced to 65%.

B. Pressure Sensor Results

As shown in Figure 12, field 3 in the ThingSpeak Server are updated with air pressure values. The server is getting updated every 13seconds. The time at which 18:25hrs air pressure in the farm 90Pa.

C. Gas Sensor Results

The fertilizer content sprayed in farm is measured using MQ-2 gas sensor. Farmer sprays the fertilizer in the farm thrice a week to protect from pests and other insects. But spraying fertilizer thrice a week is not good for the farm as it will grow with the chemical content in them. Due to growing with chemical the vegetables will spoil the heath of human beings. So monitoring the fertilizer level in the farm is very important. As shown in Figure 13, field 4 in the ThingSpeak Server are updated with fertilizer content value. At the time interval of 18:25hrs the fertilizer sprayed content is 195ppm and gradually decreasing to 178ppm and in various fields of farm it is different.

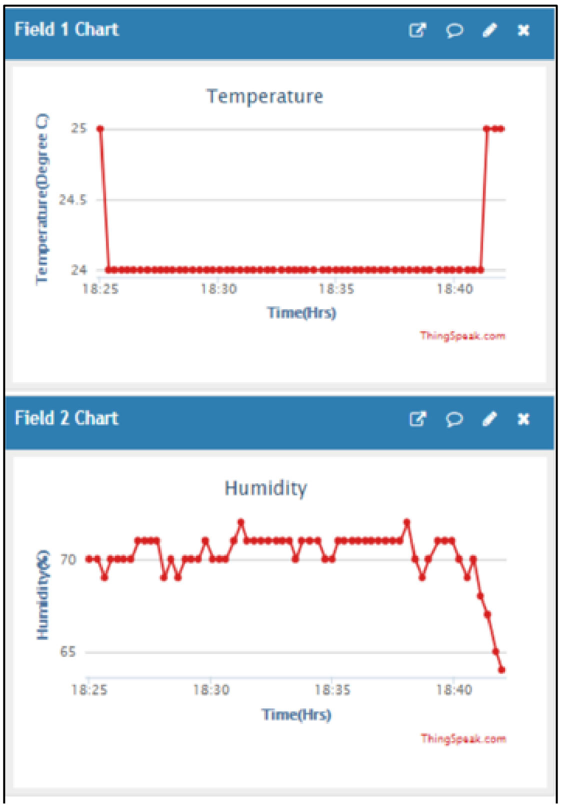

Fig. 11. DHT-11 output in ThingSpeak Server with field 1 temperature vs Time and field 2 Humidity vs Time.

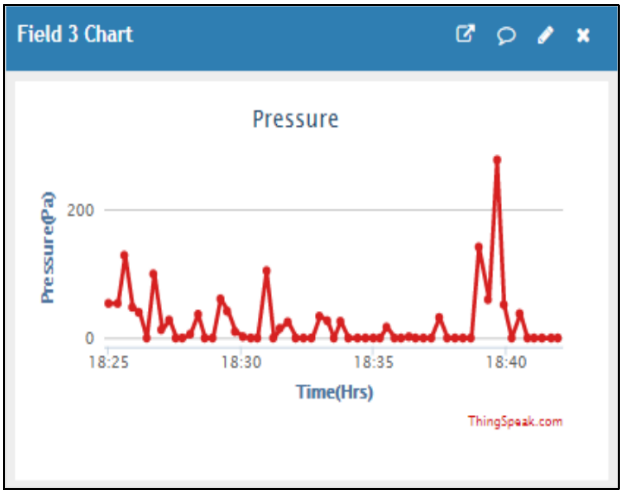

Fig. 12. Pressure Sensor output in ThingSpeak Server with field 3 Pressure vs Time.

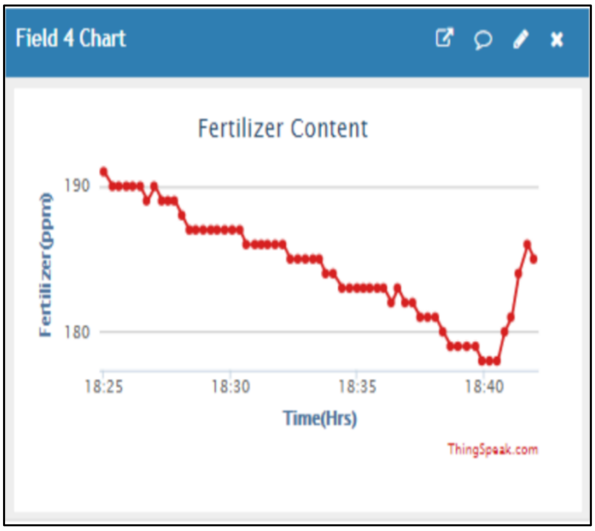

Fig. 13. Gas Sensor output in ThingSpeak Server with field 4 Fertilizer vs Time.

D. Soil Moisture Sensor and Location Results

Finally, the soil moisture values in percentage, as well as the location of the farm are updated in the Server, as shown in Figure 14.

It is observed that the value of field 5 at time 18:25hrs is 60% moisture in soil. The sensor reads the soil moisture value in analog so to convert into percentage the equation 1 is used.

$$mp = (sa/1023.00) * 100 \qquad (1)$$

In equation 1, mp is moisture value in percentage where this variable is sent into ThingSpeak server and sa is sensor analog input value.

The analog value is divided 1023 so the value of soil moisture will be converted into digital and multiplied by 100 so that the percentage of the water content in soil is measured. The location of the farm is located 17.3125° N, 78.5363° E.

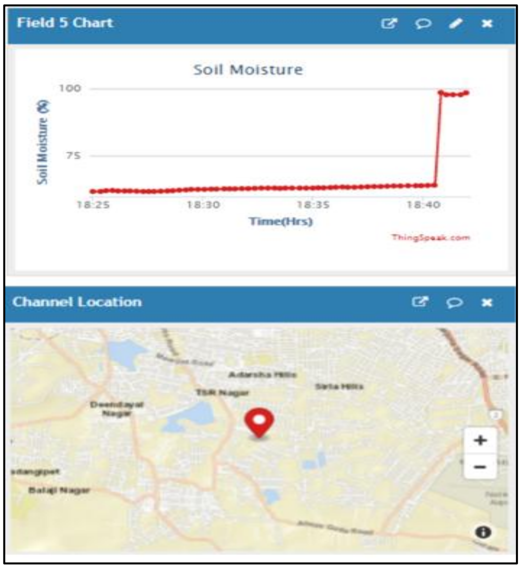

Fig. 14. Soil Moisture Sensor output in ThingSpeak Server with field 5 Soil Moisture vs. Time and field 6 Location

E. SMS Results

As shown in figure 15, the farm parameters will be sent to farmers personal mobile with the help of twilio account. Whenever the status of water motor or the exhaust fan will change from ON to OFF or OFF to ON the SMS will be triggered from the system to the farmer including all the parameters like temperature, humidity, air pressure, fertilizer content and soil moisture of his/her farm/greenhouse.

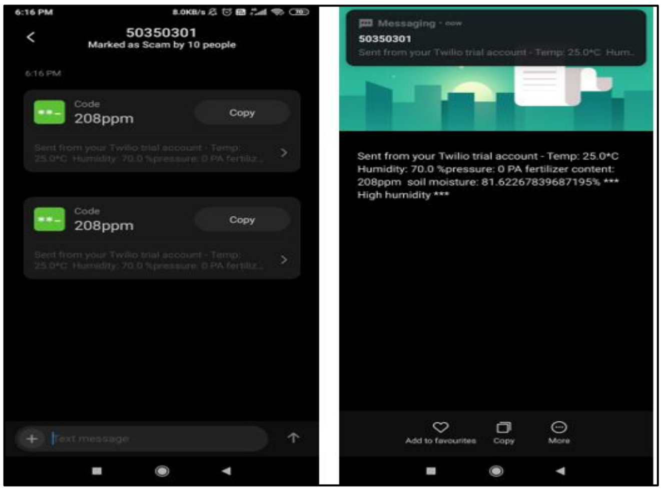

Fig. 15. **SMS Alert to Farmer Mobile**

F. ThingSpeak Mobile application

The usage of the ThingSpeak mobile application for monitoring smart farm parameters will be very useful for the farmers. After installation, the authorized users can access this information can be accessed using a user ID and password to view ThingSpeak content in their account app as shown in Figure 16 and add the channels that need to be monitored. As shown in Figure 17, after installation of the channels which are to be monitored need to add in the app with its channel ID. After adding the channel ID, all the graphs will be displayed in the application.

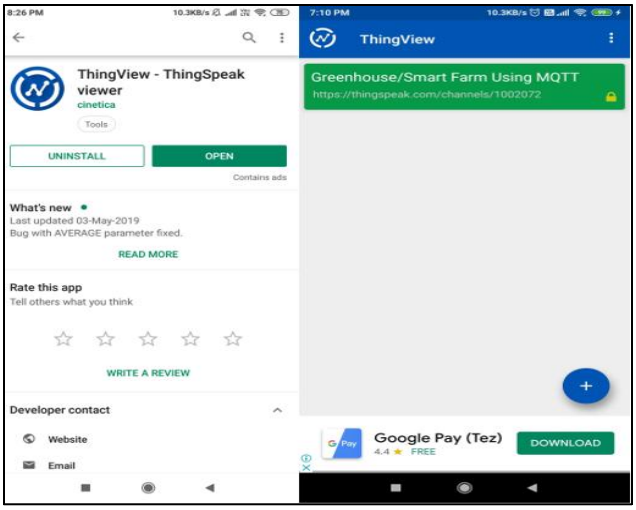

Fig. 16. ThingSpeak App Installation.

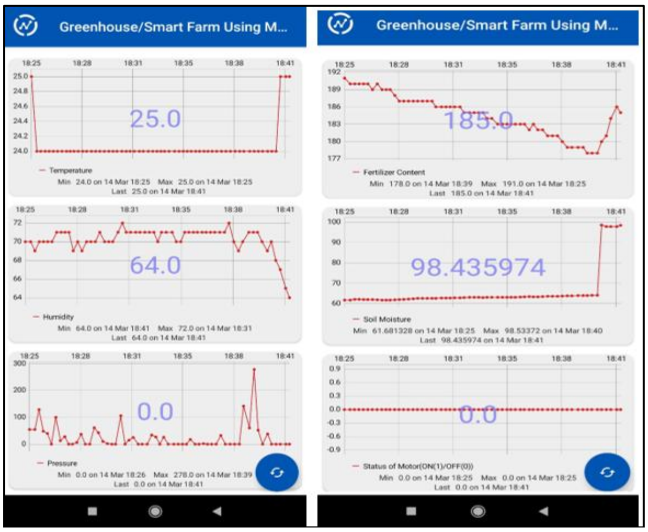

Fig. 17. All the Parameters in ThingSpeak Mobile Application

G. PHP Web Page Results

As shown in figure 18, a customized website is also created for farmers using PHP coding. In this webpage also the farmers will be updated with the status of their farm. This PHP page acts as an backup for the farmers when ThingSpeak Server is down.

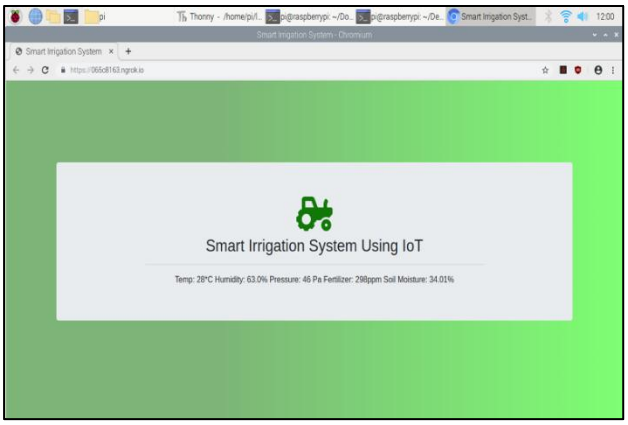

Fig. 18. Data Values on a PHP Web Page

H. Decision Tree Algorithm Results

The collected data is also further processed and given as the dataset for decision tree algorithm. 80 % of the data are used for the algorithm's training and the remaining 20% for the algorithm's test. Table 1 shows the actual and forecast parameter values.

Table 1 Prediction of Parameters using DT Algorithm

Parameters	Actual	Predicted
Temperature	24°C	25°C
Humidity	65%	66%
Fertilizer Content	177ppm	203ppm
Soil Moisture	62%	62%

VII. CONCLUSION

The system proposed in this paper is an efficient, inexpensive IoT solution for real-time smart farm/greenhouse monitoring system. The developed system has Raspberry Pi as target board and interfaced with several sensors and relays successfully. An efficient algorithm is developed in real-time, to track smart farm/greenhouse. The measured temperature value ranges from 24°C to 25°C, humidity ranging from 75% to 60% for location at that latitude and longitude. The fertilizer content sprayed 190ppm to 160ppm, soil moisture from 60% to 100% in different parts of the farm. A web-based application i.e., ThingSpeak with MQTT protocol is used for sending the parameters like temperature, humidity, pressure of the surrounding atmosphere, fertilizer content sprayed, and soil moisture through the webserver and also to customized webpage for the farmers. Further, these measured parameters also monitored in ThingSpeak mobile application. The accuracy point stand decision tree algorithm is providing 97%. Also, this work needs to be carried out to analyses the diseases detection for proper yield in crop with the help of the algorithms.

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AUTHOR PROFILE

G. Sai Teja was born in Hyderabad, Telangana, INDIA, in 1996. He received a B-Tech degree in electronics and communication engineering from Jawaharlal Nehru Technological University (JNTUH), Hyderabad, INDIA, in 2014. He is currently pursuing M. Tech in Embedded Systems and VLSI Design from Osmania University, INDIA. His research interest includes the development of new products using Embedded System design, IoT, Industry 4.0, Machine learning.

Sathish Pasika completed his B.Tech and M.Tech from JNTU University Hyderabad in 2005 and 2008 respectively. He is presently working as Assistant professor in ECE Dept., Chaitanya Bharathi Institute of Technology, Hyderabad. Having 12 years of experience in teaching and his research interest includes Embedded System Design and GNSS/NavIC applications.