Model for Intelligent Greenhouse

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I. INTRODUCTION

In the present world where every person is always in transit, they need to have access to all of their devices all the time. The solution comes with the devices having an internet connection so that it can be accessed from everywhere around the globe. This is what resulted in we call "internet of things". In the year 1999, the term "internet of things" was coined by Kevin Austin, the executive director of the Auto-ID[1]. From then IOT is in its ever-growing stage.

In general, IOT consist of anything and everything that uses some embedded technology to communicate with each other. IOT is an ecosystem of interrelated processing devices, mechanical and digital machines, physical objects, animals or people that have particular unique identifiers (UIDs) associated with it and is able to transfer information over the network without requiring person-to-person or person-to-devices communication[2].

IOT has impacted every sphere of day to day life. According to the Gartner 2011 Hype Cycle of Emerging Technologies, IOT is current at 'Technology Trigger' phase. [3] It is predicted that by the year 2020 there will be more than 26 billion IoT devices. As said the rule of IOT is that, "Anything that can be connected, will be connected."[4].

Agriculture plays a major role in a country like India. One of the modern sectors of agriculture is a greenhouse, where crops are grown in an artificial environment. Monitoring and control of the greenhouse environment are of utmost importance. Here comes the role of IOT which can monitor and control a greenhouse environment in real time[5]. It can also minimize crop disaster and increase production.[6], [7]

In this paper, we are going to present a model for implementation of a smart greenhouse ecosystem with the help of IoT devices that can monitor and control every aspect of a greenhouse, such as a temperature (DHT11 sensor), humidity, soil moisture, ambient light (LDR sensor), etc. The main aim is to reduce the cost as per power and resources and get a better yield but using those resources optimally. The greenhouse will also module itself for the type of crop it will be going to for using the specific requirement of the crop.

The rest of the paper constitutes of the related works in the same topic in section 2, IOT components used in Section 3, the proposed work in section 4, hardware components used in section 5, section 6 contains the system architecture, section 7 has the pseudo-algorithm, section 8 with information processing and extraction, section 9 constitute the decision making, finally concluding this paper in section 10 with the discussion and section 11 with the list of references.

II. RELATED WORKS

Joaquín Gutiérrez et.al [8] have developed an automated irrigation system to optimize water use for agricultural crops. Distributed WNS has been used that monitors the soil moisture and temperature in the root region of the vegetation. Using the threshold values of temperature humidity of soil an algorithm was developed and coded into a microcontroller-based gateway to regulate water supply. 90% saving of water compared to traditional irrigation practice was achieved when this system was tested on sage crops for 136 days. Since the system uses photovoltaic cells, it can be implemented in geographically isolated areas with limited water supply.

Another work done by R. Nageswara Rao et.al [9] developed a system whose goal is using a low quantity of water for crop development. The suggested model estimates the water required using the calibrated information sent from the sensors that have been used to monitor the soil humidity condition and temperature as well as the duration of sunshine per day. This system has implemented Precision Agriculture (PA) with cloud computing, that optimizes the usage of water fertilizers all the while maximizing the yield of the crops as well as helping in analyzing the weather conditions of the field.

A project done by N.Suma et.al [10] includes various features like GPS based remote controlled monitoring, leaf wetness, temperature and moisture sensing, proper irrigation facilities, intruders scaring, security etc. WSNs have been used for noting the soil properties and environmental factors continuously. The parameters that are being observed are controlled through remote devices or internet services and the operations are performed by interfacing sensors, Wi-Fi, a camera with a microcontroller. This project has been developed for farmer welfare.

In another work done by Shaik Jhani Bhasha et.al [11], the system monitors the water feeding activity in fields. This mechanism has been successfully implemented using PIC16F877A microcontroller, GSM module, water level sensors and a mobile phone with other necessary electronic devices and using these technology water motor can be turned on or off by farmers remotely.

Mohanraj I et.al [12] proposed an e-Agriculture Application based on the framework consisting of KM-Knowledge base and Monitoring modules. They focus on monitoring the data in the farming cycle so that it can advise the farmers to make profitable decisions. The paper demonstrates the advantages of ICT in the Indian agricultural sector.

Using WSNs with remotely controlled IP cameras Hui Chang et al [13] suggested an agriculture monitoring system. Temperature and humidity are mainly observed by conventional WSNs, while the design presented here integrates video of the foliage as well as information about the various environmental condition.

Nowadays precision agriculture is being used to improve efficiency and productivity in the usage of resources, thus helping to deal with the problems faced in agriculture due to climate change conditions, land quality, availability of space and labor force etc. Sangeetha A et al [14] developed a decision support system based on the combination of the wireless sensor and actuation network technology to support the irrigation management in agriculture for farmers in developing countries using Li-Fi technology, topology and routing protocols.

Network-embedded greenhouse monitoring and control system is a small-size tightly coupled network of information system components like sensors, actuators etc with limited accuracy. Stipanièev et al [15] used the 1-wire protocol and embedded web servers to develop network embedded greenhouse monitoring and control. The experimental system has been developed using Tiny Internet Interface (TINI) which collects data from local sensor networks and route them to the global network using the web servers and in order to activate the actuators, it uses 1-wire local network. The major advantages of Network Embedded System Technology like changing physical topology, low cost and space requirement wrt to PC based systems while maintaining the complete functionality has been achieved by the system.

Yunseop Kim et al [16] designed a system for variable rate irrigation, WSN and real-time in-field sensing software and control of a site-specific precision linear-move irrigation system. Six in-field sensors were used to monitor field conditions site specifically depending on the soil property map. Programming logic used to control the irrigation machine also sends periodic georeferenced information of sprinklers to base stations. A user interface has also been developed for real-time monitoring of the variable irrigation rate.

Shen Jin et al [17] developed a remote measurement and control system for a greenhouse using GSM-SMS. The architecture comprises of central station and base stations. The central station manages the GSM module and database system while the base stations microcontroller, sensors, the operation administer, and GSM module. The design also uses embedded operating systems which make it easy to extend the system, maintenance etc.

III. IOT COMPONENTS

1. Smart devices and sensors: These constitute the Things in the IoT ecosystem. These things can be anything starting from a cell phone to sensors like temperature, humidity etc. which are interconnected with each other. [18] Here we have used sensors like the CO2 sensor, LDR sensor, DHT11 temperature, and humidity sensor, a soil moisture sensor, and the ph. sensor. Reading from these sensors will be the deciding factor to use the other components like the motor pump, water pump, exhaust fan, exhaust fan, and artificial light.
2. Gateway: It is the layer between the cloud and the sensors module which also ensures security. Its main aim is to smoothen the bi-directional data flow between the sensors, protocols, and networks.
   We use Arduino Mega connected with ESP8266 as the gateway platform from where the data from the sensor is directed to the cloud.
3. Analytics: It converts the analog data obtained from the sensor and other devices and converts it to digital form which can be easily understood by the machine.
   Here Arduino Uno takes analog data from the sensor as input and transforms it to a digital output the can be easily interpreted. [19]
4. Cloud: The large bulk of data created is managed and handled by the cloud. It is an optimized network of servers for high-performance data processing.
   We have used HPE UIOT Platform for the purpose of data management and processing. [20]
5. User Interface: It is the topmost layer of an IOT Ecosystem visible and used by the user. It can be anything from an Android Application to a Web-Based Platform.

IV. PROPOSED WORK

The model is a miniature model of a working greenhouse environment monitored and controlled in real time. An agricultural environment consists of temperature, humidity, soil acidity, soil moisture, and ambient light present; all of these components can be monitored and artificially altered using IoT sensors and devices, hence maintain a constant most optimal condition for a crop's best yield. Moreover, these conditions will adapt itself no matter how harsh the outside condition is. The greenhouse environment can be made optimal for a specific crop with an easy-to-use mobile application.

V. HARDWARE COMPONENTS

For this IOT ecosystem different hardware and software components are used for the various components of IOT.

Components which sense the environment:

1. **Arduino Mega**: It is an open source processing device having the ATmega2560 programmable microcontroller with a clock speed of 16 MHz with auto-reset. It takes a power input of 12V. It has a USB plug to upload or burn the program to the microcontroller.[21] It has a set of analog and digital pins where respective inputs/outputs are fed into. It is connected with an ESP8266 Wi-Fi Module that enables the Arduino to have an internet access.[22] The microcontroller sends data to the cloud for processing with the help of this Wi-Fi module.[23] Fig. 1 shows Arduino Mega. Fig. 2. shows the ESP8266 Wi-Fi module. It forms the gateway for the IoT ecosystem.

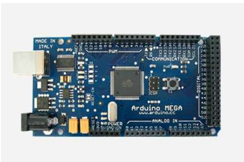


Fig. 1

Fig. 2

2. **DHT11**: It is a low-cost humidity and temperature sensor requiring a 5V power supply. It has a range of 20-90RH for measuring humidity with ±5% accuracy and has a range of 0-50º C for measuring temperature with an accuracy of ±2º C. It uses two-way single wire serial interface. It has a three-stage communication consisting of the request, response, and data reading. It contains a thermistor whose resistance changes with the change in temperature. Humidity is measured with the help of two electrodes separated by a moisture holding substrate between them. So as the humidity of atmosphere changes the resistances also changes and we can get the value using this formula. Fig. 3 is a DHT11 sensor. [24],[25]

- For temperature sensing :

  Temperature = (Vout * 100) / 5º C
- For humidity sensing :

  RH = ((Vout / Vsupply) - 0.16) /0.0062 %

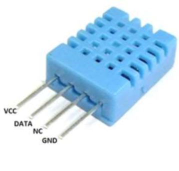


Fig. 3

3. **MG811**: It is a reliable and stable CO_2 sensor and has a low dependency on humidity and temperature. The module has both digital and analog output.[26]

When the sensor exposed to CO2, the following electrodes reaction occurs and gives us the CO_2 concentration in the atmosphere.

Fig. 4

4. **Soil-Moisture LM-393**: It is a cost effect and reliable soil moisture content detection module that work on 5V supply. It consists of two metal rods (Fig. 5) held apart through which current passes. The resultant resistance is high when soil moisture is low and vice-versa. The module is fitted with a potentiometer that can vary the sensitivity of the sensor. [27]

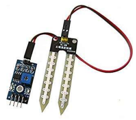


Fig. 5

5. **LDR LM-393:** It is an LDR module to detect the presence of ambient light intensity in the environment. It uses Cadmium Sulphide for the register material. The resistance of the LDR (light dependent resister) changes with the change in intensity of light. The LM-393 module has both analog and digital output pin.

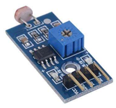


Fig. 6

6. **pH-Sensor:** It is low power (5V) soil pH sensor to measure the acidity of soil(Fig. 7). It has two components.
   i. pH probe: It has one glass and one reference electrode. Both of these are a hollow tube containing Silver-Chloride wire in Potassium-chloride solution. It compares the liquid inside the glass electrode which is known and compares it with the unknown liquid outside.
   ii. pH sensor; it has a potentiometer that can vary the sensitivity of the sensor.

Fig. 7

All the components sense the environment and provide the information to the Arduino Mega which in turn processes the data and convert into a percentage. This value is then forwarded to the cloud for further processing in JSON format.

Components which control the environment-

- Peltier Module- This is a cooling and heating unit which will control and balance the temperature to achieve optimum temperature.

- Exhaust Fan- To control the CO_2 percentage as per standard level
- Air Humidifier- To maintain a humidity level of the air.
- Acid Sprinkler- To maintain an acid level of the soil.
- Alkaline Sprinkler- To maintain alkalinity level of the soil.
- Artificial Light- To provide artificial optimum lighting.

These components take the processed information from the cloud and set the environment inside the greenhouse best suited for optimum crop growth.

VI. System Architecture

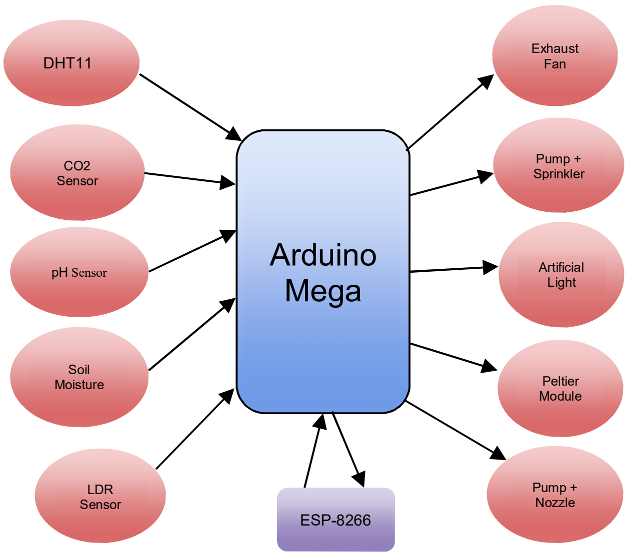
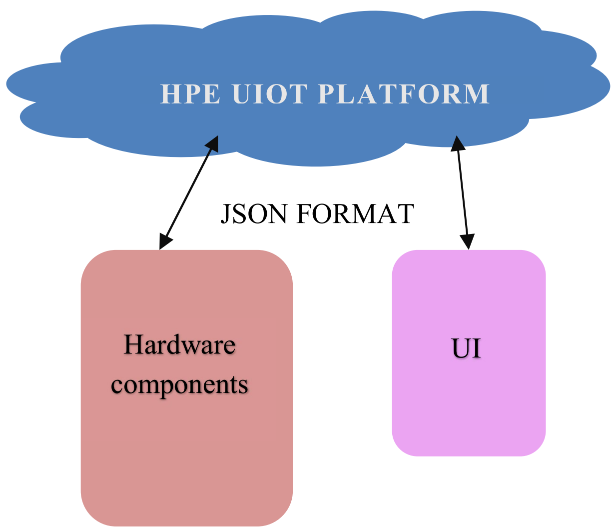


Fig. 8

Fig. 8 show all the hardware contents of this ecosystem consisting of sensors and components to control the artificial environment. All the input sensors provide the environment information in the form of analog voltage ranging from 1-1024 (10bit) and one-wire data (DHT11). These data are then processed and converted to a readable percentage or rounded figures which can easily be calculated or used as a reference for easier decision making. The data are converted from analog voltageto respective environmental values which are then forwarded to the cloud in JSON format, then the necessary decision made on the cloud side and necessary steps for control are sent to the Arduino for steps to be taken. The respective environment data and controls are sent to Android UI as notifications. As it is shown in Fig. 9 the two-way data transfer from hardware components to cloud and the ui, the data is encoded in JSON format as that's the default input/output type of the HPE UIOT Platform.

Fig. 9



VII. Pseudo-Algorithm

Algorithm overview of the application

Start

1. Acquire sensor data continuously.
2. Analog/Digital conversion of the sensor data on the Arduino Board
3. Transmission of the data to the cloud through the IOT Gateway (Arduino Mega + ESP8266)
4. If the data is above the threshold
   a. Server (i.e. cloud) automatically Turns ON the control measure
   b. Send a notification to the Smart Farming Application
5. If the data is within a threshold
   a. Server (i.e. cloud) automatically Turns OFF the control measure
   b. Send a notification to the Smart Farming Application
6. Else
7. Continue checking for the threshold condition
8. Endif

End

VIII. Information Processing and Extraction

The system architecture consist of an Arduino Mega microcontroller board, sensors like DHT11 temperature & humidity sensor, a moisture sensor, LDR Sensor, pH Sensor, CO2 Sensor, a Wi-Fi module i.e. ESP8266. The software consists of an android application which includes setting up of the profile for predefined irrigation based on the seasons or on daily and weekly mode. The software has also been programmed to send a notification to the farmer whenever the physical parameters sensed are below the threshold value and based on the farmers input a control signal will be sent to the Arduino Mega to either switch ON/OFF the irrigation. The Arduino Mega board controls all the activities taking place on board and acts as the IoT gateway. The sensor senses all the physical parameters and converts the analog value to digital value. Temperature and humidity sensors are used to measure the temperature and humidity respectively on the field. Soil Moisture Sensor is of a capacitive type and is used to measure the moisture of the soil.

This data is then transmitted to the IOS gateway. The IOT gateway then transmits the data to the cloud using the Wi-Fi module. The cloud in our system will include a Web Server, a database and a decision logic. The database will maintain the data received from the IOS gateway. The decision logic then decides whether the farmer action is needed to water the plants. For example, in the developed system a threshold for temperature is kept at 25 ◦C. Whenever the temperature goes above the threshold temperature, the database will trigger an action to the decision logic which then sends a notification to the developed Smart Farming Android application. The farmer will also get notified by an SMS to his registered mobile phone. Based on the farmer's action whether to turn ON/OFF the watering, a signal will be sent to the cloud and from the cloud to the gateway which will then send a signal to trigger the relay and turn on the water pump.

IX. Decision Making

If	Then
Soil moisture level low	Turn on sprinkler
Soil moisture level ok	Turn off sprinkler
CO2 high	Turn on exhaust
Co2 ok	Turn off exhaust
Humidity level low	Tun on sprinkler
Humidity ok	Turn off sprinkler
Ph low	Turn on the alkaline sprinkler
Ph high	Turn on the acidic sprinkler
Ph balanced	Turn off acidic and alkaline sprinklers
Temperature high	Turn on Peltier modules and turn on the servo to cool down mode
Temperature low	Turn on Peltier modules and turn on the servo to heat up mode
Ambient light low	Turn to Artificial light to a certain light level

X. Conclusion And Discussion

XI. References

[1] Ashton K., “That ‘Internet of Things’ Thing,” *RFID J.*, p. 4986, 2009.

[2] “What is internet of things (IoT)? - Definition.” [Online]. Available: https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT. [Accessed: 10-Dec-2018].

[3] J. Gubbi, R. Buyya, and S. Marusic, “Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions,” *Atmos. Environ.*, no. 1, pp. 1–19, 2013.

[4] Jacob Morgan, “A Simple Explanation Of ‘The Internet Of Things.’” [Online]. Available: https://www.forbes.com/sites/jacobmorgan/2014/05/13/simple-explanation-internet-things-that-anyone-can-understand/#557bed561d09. [Accessed: 10-Dec-2018].

[5] D. Liu, X. Cao, C. Huang, and L. Ji, “Intelligent agriculture greenhouse environment monitoring system based on IOT technology,” *Proc. - 2015 Int. Conf. Intell. Transp. Big Data Smart City, ICITBS 2015*, pp. 487–490, 2016.

[6] K. A. Patil and N. R. Kale, “A model for smart agriculture using IoT,” *Proc. - Int. Conf. Glob. Trends Signal Process. Inf. Comput. Commun. ICGTSPICC 2016*, pp. 543–545, 2017.

[7] G. Sushanth and S. Sujatha, “IOT Based Smart Agriculture System,” *Int. J. Recent Innov. Trends Comput. Commun.*, vol. 2, no. February, pp. 177–181, 2017.

[8] J. Gutiérrez, J. F. Villa-Medina, A. Nieto-Garibay, and M. Á. Porta-Gándara, “Automated Irrigation System Using a Wireless Sensor Network and GPRS Module,” *IEEE Trans. Instrum. Meas.*, 2013.

[9] R. Nageswara Rao and B. Sridhar, “IoT based smart crop-field monitoring and automation irrigation system,” *Proc. 2nd Int. Conf. Inven. Syst. Control. ICISC 2018*, no. Icisc, pp. 478–483, 2018.

[10] N. Suma, S. R. Samson, S. Saranya, G. Shanmugapriya, and R. Subhashri, “IOT Based Smart Agriculture Monitoring System,” *Int. J. Recent Innov. Trends Comput. Commun.*, vol. 2, no. February, pp. 177–181, 2017.

[11] S. J. Bhasha and S. M. Hussain, “Agricultural field monitoring and automation using PIC16F877A microcontroller and GSM.,” vol. 3, no. 6, pp. 2155–2157, 2014.

[12] I. Mohanraj, K. Ashokumar, and J. Naren, “Field Monitoring and Automation Using IOT in Agriculture Domain,” *Procedia Comput. Sci.*, vol. 93, no. December 2016, pp. 931–939, 2016.

[13] H. Chang, N. Zhou, X. Zhao, Q. Cao, M. Tan, and Y. Zhang, “A new agriculture monitoring system based on WSNs,” *Int. Conf. Signal Process. Proceedings, ICSP*, vol. 2015–January, no. October, pp. 1755–1760, 2014.

[14] A. Sangeetha, P. Sarah, and G. Poovarasi, “IOT BASED HYBRID SYSTEM FOR PRECISION AGRICULTURE MONITORING USING WSN

INTO MODERN INFORMATION AND COMMUNICATION TECHNOLOGY (ICT),” no. 2, pp. 3116–3124, 2018.

[15] D. Stipanicev and J. Marasovic, “Networked embedded greenhouse monitoring and control,” *Control Appl. 2003. CCA …*, pp. 1350–1355, 2003.

[16] Yunseop (James) Kim, R. G. Evans, and W. M. Iversen, “Remote Sensing and Control of an Irrigation System Using a Distributed Wireless Sensor Network,” vol. 57, no. 7, pp. 1379–1387, 2008.

[17] J. Shen, J. Song, Q. Han, S. Wang, and Y. Yang, “A remote measurement and control system for greenhouse based on GSM-SMS,” *2007 8th Int. Conf. Electron. Meas. Instruments, ICEMI*, pp. 282–285, 2007.

[18] “What are the major components of Internet of Things - RF Page.” [Online]. Available: https://www.rfpage.com/what-are-the-major-components-of-internet-of-things/. [Accessed: 12-Dec-2018].

[19] “IoT Ecosystem Components: The Complete Connectivity Layer.” [Online]. Available: https://www.newgenapps.com/blog/iot-ecosystem-components-the-complete-connectivity-layer. [Accessed: 10-Dec-2018].

[20] “Universal Internet of Things (IoT) Platform | HPE India.” [Online]. Available: https://www.hpe.com/in/en/solutions/iot-platform.html. [Accessed: 14-Dec-2018].

[21] “Arduino Reference.” [Online]. Available: https://www.arduino.cc/reference/en/. [Accessed: 16-Dec-2018].

[22] M. Mehta, “ESP8266 : A Breakthrough in Wireless Sensor Networks and Internet of Things,” *Int. J. Electron. Commun. Eng. Technol.*, vol. 6, no. 8, pp. 7–11, 2015.

[23] L. Louis, “Working Principle of Arduino and Using It As a Tool for Study and Research,” *Int. J. Control. Autom. Commun. Syst. (IJCACS), Vol.1, No.2, April 2016*, vol. 1, no. 2, pp. 21–29, 2016.

[24] Mouser Electronics, “DHT11 - Humidity and Temperature Sensor,” *Datasheet*, pp. 1–7, 2011.

[25] J. He, J. Qu, Y. Wang, and H. Pan, “The designing and porting of temperature &humidity sensor node driver based on ARM-Linux,” *Proc. - 2014 IEEE Work. Electron. Comput. Appl. IWECA 2014*, pp. 127–130, 2014.

[26] Telaire, “7001i CO2 Sensor,” vol. 2013, no. 2/5/2013, pp. 2–3.

[27] Datasheet, “LMx93-N , LM2903-N Low-Power , Low-Offset Voltage , Dual Comparators,” no. 1, 2018.