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IoT based Automated Indoor Agriculture System Using Node-RED and IBM Bluemix

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***Abstract*— Farming is the backbone of agriculture, which makes a considerable contribution towards the GDP growth of a country. Owing to the disadvantages of traditional outdoor framing. Indoor Farming has been considered as a more sustainable method in recent times. This project aims to automate some of the processes of indoor agriculture by monitoring the parameters that contribute to a healthy crop growth such as temperature, humidity and machine temperature, light intensity and pH levels, and automating them to stay within the optimal range, where possible, or alert the owner of the estate to take necessary action immediately. The sensor data is simulated using IBM IoT sensors and is sent to the cloud through IBM Bluemix. The data is transmitted to the Node-RED platform by using MQTT protocol. A mobile application has been developed for the farm owner to access all details related to the statistics of parameters that are gathered by the sensor data and keep track of their farm from anywhere. In doing so, the indoor farm can facilitate agriculture without the need for excess manual labour.**

Keywords*— *Automated agriculture, IoT, Node-RED, MQTT, IBM Bluemix, mobile application.

I. INTRODUCTION

Indoor farming has gained popularity in recent years, as technology has become even more precise, thereby allowing large amounts of fresh produce to be grown in urban environments, with reduced water requirement as compared to outdoor farming and minimal space. Almost one third of India's total population reside in cities by 2019. Urbanization faced an increase of around 4% during the last decade.

In the case of traditional outdoor farming, it has been observed that the cultivable land is shrinking from year to year. Unfavourable weather conditions and pesticides also decrease the fertility of soil, globally. In addition to this, crops cannot be grown around the year. Eventually, this would lead to shortage in the land to grow and cultivate crops and may also lead to other issues such as water wastage and unhealthy crop growth due to pests and weeds. Indoor farming methods could help in conserving rainforests and land, by allowing the replenishment of topsoil and a reduction in carbon consumption. In 2019, India lost 115kha of forests due to deforestation, which is equal to 43.5Mt of CO_2 emissions. Countries like Qatar and Netherlands have a full-fledged market for indoor farming. In the year 2019, Qatar and Netherlands had a GDP contribution about 0.18 percent and 17.8 percent from agriculture sector respectively.

Although there has been consideration that indoor farming is a more sustainable option for agriculture as compared to traditional outdoor farming, need of manpower to tend to the farm and growth of the crops still emerges as a concern. With rising technology, automating the processes of agriculture in indoor farms can prove to be a boon and great support to the farmers. This can help in reducing costs that would be required to pay manual labour as well as the costs that would be spent on machine maintenance if there is a breakdown in machines due to negligence.

The crop chosen for our project is Lettuce, owing to its low to no soil requirements due to its shallow root system. By monitoring the parameters that contribute to healthy plant growth such as weather conditions, intensity of light, and soil conditions, and regulating them in order to ensure the crop grows under optimal conditions, the agriculture process can be automated and increase efficiency. In our project, the sensor data has been simulated using IBM IoT sensors and Node-RED. All simulated sensor data is sent to the cloud using IBM Bluemix and is transmitted to Node-RED through MQTT.

Node-RED has been chosen due to its efficiency in connecting hardware, online services and APIs together to build applications, with a simple drag and drop functionality. A Node-RED based service is integrated to IBM Bluemix so that all resources connected to Node-RED can be accessed by IBM Bluemix, which allows for integration of third-party services, creation of applications and cloud usage under a single platform.

Temperature, humidity and light intensity data values are sensed and adjusted to be brought back to their optimal range in case the conditions turn unfavourable. The owner is also notified if the soil pH level turns too acidic or too basic, in order for them to replace the soil. All the sensor data is sensed and then computed on a central system that is connected to the sensors and the actuators. Supposing the central system faces an overheating situation, a possible system breakdown may occur, leading to the automated system failing. The farm owner receives a notification via our app, in case of potential overheating, to take immediate action in order to avoid this. This facilitates system maintenance instead of a system breakdown and saves the cost of repair. The owner of the farm can keep a track of the status of his farm and sensor data from anywhere, at any point in time via a mobile application. This entire process will enable the farm owner to cut costs and reduce manpower, while still ensuring the quality of his crop remains high.

II. Related Work

Shomefun, T. E., OA, A. C., & Diagi, E. O. et al. (2018) proposed automating the drip irrigation process by deploying solenoid valves and a DC water pump, which are controlled using the Arduino Uno microcontroller [5]. K. Swarna Krishnan, K. Jerusha, Poonam Tanwar, Shefali Singhal et al. (2020) suggested that the tasks of weeding, spraying, moisture sensing and vigilance were automated using a GPS based robot, connected to the Internet, and the operations were performed by using sensors, Wi-Fi modules, and actuators with microcontroller and raspberry pi [1]. Sahu, T., & Verma, A. et al. (2017) set up an Automated Sprinkler irrigation system that provides control for soil temperature, moisture sensing, and also giving an interrupt signal to the raspberry pi [6].

Soni, D., & Makwana, A. et al. (2017) drew a survey on the importance of MQTT protocol in IoT applications and concluded that it is the most efficient protocol that facilitates device to device communication owing to its lightweight and high productivity [8]. Kodali, R. K., & Anjum, A. et at. (2018) used Node-RED to develop a home automation system where sensor data communicates with the platform through MQTT using a Mosquitto broker and automation is achieved [4].

IoT's vision is for every object on a network to be uniquely identified, and for it to be accessible to the network, with services and intelligence included. It blends the world with a virtual world of digital technology [7]. Nakhuva, B., & Champaneria, T. et al. (2015) assessed various IoT platforms to find the most suitable one. In terms of the best platform to use to integrate to the application and connect to the cloud, it can be concluded that IBM Bluemix is one of the most apt cloud platforms due to its power of app creation, management support, and third-party API and services that it provides to its users.

IBM cloud services are essential as they reserve cloud provisioning and have incorporated groups for kits with expansion, disposition, processes execution, and distribution at computerized dimensions. It is an effective tool when it comes to hybrid cloud computing [2].

Muis, A., & Auliyaa, A. D. et al. (2019) designed a vehicle monitoring system that uses Flutter as a means to relay the aggregated comprehensive information to the user. The GUI display on Android has the ability to present stylish digital gauge indicators. [3]

Considering the drawbacks of traditional outdoor farming, indoor farming is considered as a more sustainable method for agriculture. Nevertheless, this method of farming is also comes with a set of disadvantages. These include a high cost for installation of the set-up and high operational costs. Indoor farming also consumes a high amount of power. In addition to this, there is a high requirement of manpower to maintain an indoor farm.

III. Proposed System and Implementation

The objective of our project is to automate the process of indoor agriculture. IBM IoT sensors are used to simulate sensor data of room temperature, humidity and machine temperature parameters. Sensor data is also gathered for light intensity and soil pH conditions. This sensor data is integrated to Node-RED. For room temperature, humidity and light intensity parameters, the sensed value is compared and it is checked whether the value falls under the optimal range of their values. If not, the values are regulated to a value in the optimal range and the regulated values are sent to thermoelectric actuators, humidifiers and light intensity control actuators, respectively. In case the soil pH level is found to be higher or lower than the optimal range, a notification is sent to the farm owner via an application so that the soil can be replaced, in order to promote healthy crop growth.

The sensor data is received and actuation is carried out by a central processing system. Suppose the processing system tends to overheat, the automated system could potentially break down. In order to avoid this, if the system's temperature is rising and about to reach overheating temperature, a notification is sent to the farm owner so that he can tend to the situation. All of this data can be accessed by the farm owner anywhere, at any point in time. The app is developed using Flutter framework.

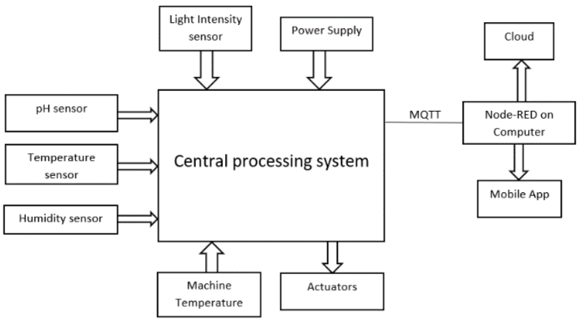

Fig. 1. Block Diagram of Proposed System

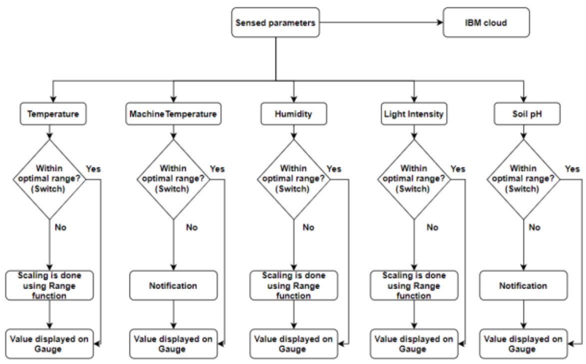

Fig. 2. Flowchart of parameter actuation

The implementation of the proposed system is carried out as follows:

A. Interfacing IBM Bluemix with Node-RED

Node-RED based browser editor and IBM Cloud have been made major use of to implement this project. In order to access IBM Cloud, one must register and create an account first. The browser-based editor allows you to drag and drop nodes which can be wired together and deployed by a single click. A Node-RED service is created using the IBM Cloud platform in order to connect the IBM IoT sensors and also to store the data in the cloud. The Node-RED app is created and the Continuous Delivery feature is enabled once the app has been deployed into the Cloud Foundry space. It is essential to create an IBM Cloud API key to be able access one's resources. After the Node-RED application has been created, the app URL is created which links the editor to IBM. Authentication details are configured and access to the Node-RED UI is gained. The three IBM IoT sensor simulators-temperature, object temperature and humidity are connected to Node-RED using the IBM IoT node. The sensor simulators can be controlled by using the buttons and the data is published periodically.

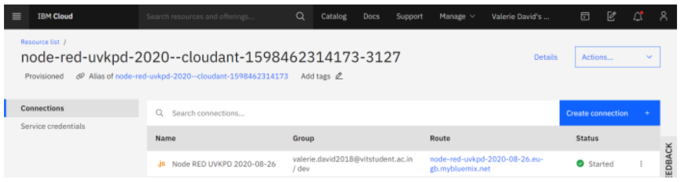

Fig. 3. Creating a Node-RED service on IBM Cloud.

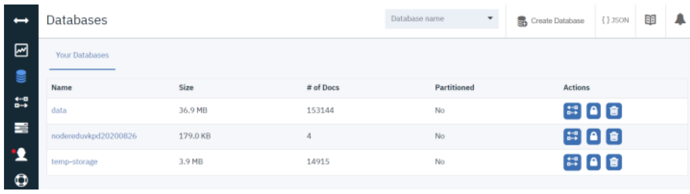

Fig. 4. Sensor data from Node-RED is connected to the cloud database.

B. Obtaining sensor data on Node-RED through MQTT and IBM IoT

Message Queuing Telemetry Transport (MQTT) is a communication protocol of the publish/subscribe type, which allows a network of protocol devices to publish data to a broker. The broker acts as a mediator to communicate between devices. Every device can "subscribe" to a certain topic and when a message is published by another client on the subscribed topic, the message is forwarded by the broker to the client that subscribed to that specific topic. Due to its lightweight, efficiency and bidirectional capabilities, MQTT significantly increases the capacity of data that can be monitored. It plays an important role of communication in IoT projects by facilitating the connections between devices, servers, and applications.

While MQTT and CoAP (Constrained Application Protocol) are both useful as IoT protocols, MQTT is preferred as it administers Quality of Service and secures the delivery of messages more efficiently.

The IBM IoT platform acts as a broker and hence, distributes messages to connected clients. The IBM IoT node in Node-RED allows for the sensor data to be sent and computed. IBM IoT sensor simulator is started and the device ID is configured onto the IBM IoT node in Node-RED, which then transmits data into the flow. Node-RED then acts as the subscriber and accepts the incoming sensor data (here, temperature, humidity and object temperature) and processes it.

An Aedes MQTT broker is installed on Node-RED which enables communication via an MQTT broker without the need to install an external broker such as Mosquitto. In order to simulate sensor data for soil pH and light intensity, the Inject and Function nodes are used to generate random values within a certain range, and be injected periodically. The sensor data is then published to the MQTT in nodes. MQTT out nodes subscribe to the sensor data respectively, and this is used for computation and automation, as well as to send the data to the cloud.

Once the sensor data has been computed and regulated when necessary, MQTT acts as a gateway and transmits data to the load (the actuators), through Wi-Fi.

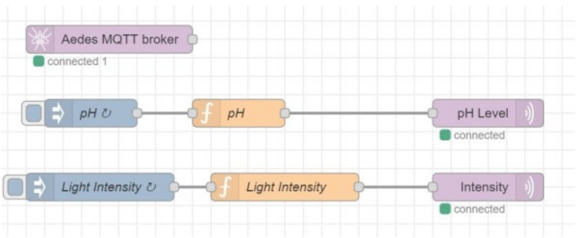

Fig. 5. Publishing data using MQTT.

C. Automating the processes using Node-RED

The optimal ranges of different parameters required for the healthy growth of Lettuce are:

- Temperature -18.3 degree Celsius to 23 degree Celsius
- Humidity - 50% to 70%
- Soil pH - 6 to 7
- Light intensity - 400 µmol/m^{2}s to 600 µmol/m^{2}s
- Machine overheating temperature - over 70 degree Celsius

In the flow editor, the ibmiot node is dropped and configured. The Cloudant OUT node is used for temporary storage of data from the sensors. Cloudant console is launched from the IBM Cloud Dashboard. The sensor values obtained, namely-temperature, humidity and object temperature- from the ibmiot are connected to a function node in order to separate them and perform operations accordingly. In order to simulate sensor values for pH and light intensity, the Inject and Function nodes were used to send random values within a certain range (5.5-7.5 for pH and 200-950 for light intensity) at regular intervals to the MQTT node.

Temperature value is connected to three switch nodes-one for checking if it is above the optimal range, below the required range, or within the optimal range. The switch nodes act as a conditional statement. The dashboard package acts as a prerequisite for using the gauge node. While the value is within the optimal range, its sensed value is directly displayed on the dashboard whereas in the other case, it is wired to the range node that it scales the value of the parameter back to its optimal range. This value is then connected to the MQTT out node to be sent to the actuator. The same procedure is carried out for the humidity and light intensity parameters as well and their values are regulated to be within the optimal range.

For soil pH levels, a notification is sent to the farm owner indicating if the level sensed is higher or lower than the optimum level, in order for the soil to be replaced. Two switch nodes have been incorporated to perform this task. In case the processing system approaches an overheating temperature, a notification is sent to the farm owner using a notification node, which is attached to the switch nodes to perform this operation.

Multiple dashboards can be created. Three gauges are present in one dashboard and the other two in one each. A panel at the left which allows the user to switch between the dashboards, allowing data to be viewed comfortably. This data from Node-RED is made available to the user through a mobile app which can be accessed from remote locations.

D. Integration with Mobile Application

The mobile application has been developed with the use of Flutter SDK. This has allowed us to be really flexible on our app. With flutter, we were able to use the BloC architecture to create our authentication page. Upon starting the app, this would be the first screen (unless you logged in previously). This involved the use of Firebase to store the credentials of the user as well as storing the authentication token locally. After authentication, the user is directed to the home screen, where all the stats of the different sensors are shown. To always show the latest updated readings, we chose to use a WebView package that directly gets data from the Node-RED dashboard. This application also has an option to hide the data that we receive while the application is open. It also has a logout functionality that sends the user back to the authentication screen.

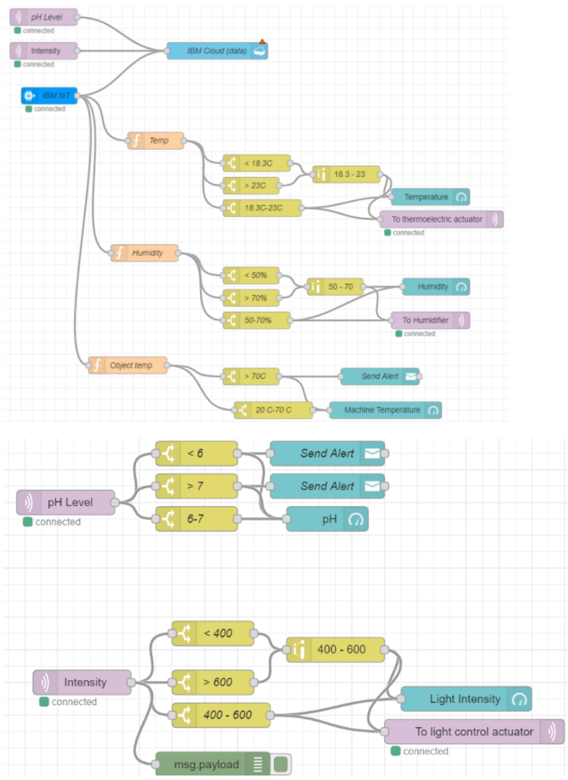

Fig. 6. Node-RED Flow

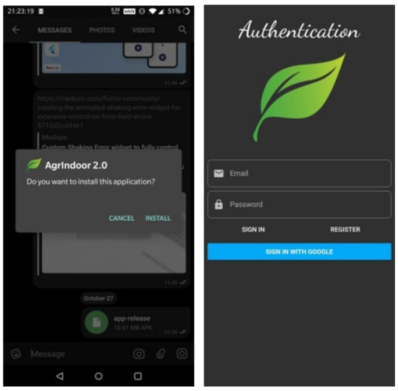

Fig. 7. Mobile Application Install and Authentication page

IV. RESULTS

Thus, we have successfully created a Node-RED implementation using IBM Bluemix, and communication through MQTT, in which we read data from the IBM sensor and determine the best course of action with regard to the anomalies of the incoming readings. As shown in the images below, in the case of temperature, humidity and light intensity, we have successfully implemented a system where the readings out the limits of the optimal range for the parameters are actuated back to viable values.

The actual values can be seen on the IoT sensor simulation whereas the regulated values can be viewed on the app screen. All these readings have been successfully shown to the user via the mobile application, as well as on the Node-RED dashboard website. In case the parameter cannot be automated to the desired range, such as in the case of soil pH and machine temperature readings, if the value is out of range, a notification pops up on the user's screen, so as to let them manually take the required action.

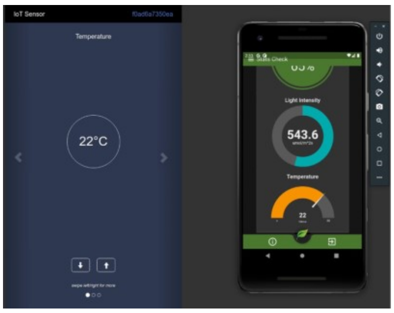

Fig. 8. App view with readings for temperature within the optimal range, as shown in IBM IoT sensor simulator.

Fig. 9. App view with regulated readings for temperature less than and greater than optimal range, as shown in IBM IoT sensor simulator.

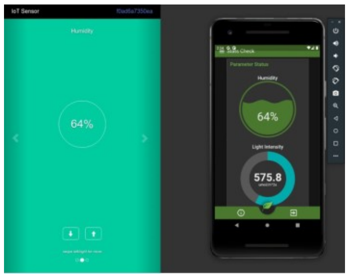

Fig. 10. App view with readings for humidity within optimal range, as shown in IBM IoT sensor simulator.

Fig. 11. App view with regulated readings for humidity less than and greater than optimal range, as shown in IBM IoT sensor simulator.

Fig. 12. App view for machine temperature within and greater than optimal range, as shown in IBM IoT sensor simulator. Notification pops up in case the temperature is greater than 70°C, alerting the user.

Fig. 13. App view for pH levels less than, within and greater than optimal range. Notification pops up when pH level is less than 6 or greater than 7, alerting the user.

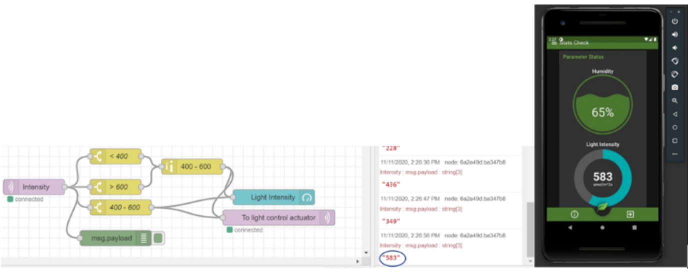

Fig. 14. App view with readings for light intensity within optimal range.

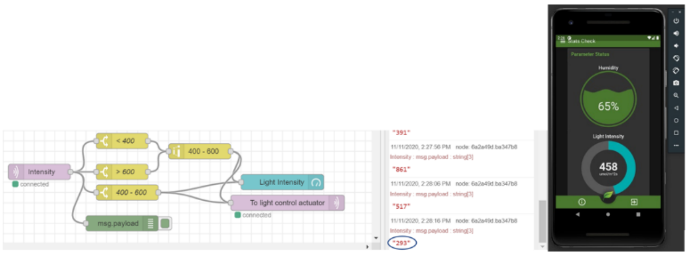

Fig. 15. App view with regulated readings for light intensity out of optimal range.

Thereby, the proposed method is more efficient than conventional IoT monitoring systems as it not only monitors the values and keeps the farm owner updated but also automates essential parameters leading to healthy plant growth, where possible.

V. CONCLUSION AND FUTURE WORK

Our project was successfully built using Node-RED, IBM Bluemix and sensor simulators and has been exclusively designed for the cultivation of Lettuce plants under indoor farming or greenhouse conditions. This project can be implemented for other crops too and for large scale outdoor farming by making few developments. The project can be further improved by incorporating more sensors, drones and robotic bots for various activities. This would help in monitoring the crop and soil, drones help with pesticide spraying, fertilizer spraying and also thermal, multispectral imaging, etc.

Conventional greenhouses still depend on human labour to control environmental parameters such as light intensity, humidity, temperature, etc. Since machines tend to be more precise, mistakes don't happen and a greater yield can be expected with higher profits. There are a few things which need to be taken into consideration while incorporating smart farming techniques-ensure that the sensors are of good quality, choosing suitable AI algorithms for data analysis, proper maintenance, good data security and connectivity.

In the future, IoT technologies will be able to provide better food traceability which would guarantee food safety. Smart farming is also considered to be sustainable due to the optimization of land, water, fuel and other natural resources.

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