

Internet of Things (IoT) for Smart Precision Agriculture

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Abstract

The scarcity of clean water resources around the globe has generated a need for their optimum utilization. Internet of Things (IoT) solutions, based on the application-specific sensors' data acquisition and intelligent processing, are bridging the gaps between the cyber and physical worlds. IoT based smart irrigation management systems can help in achieving optimum water-resource utilization in the precision farming landscape. This paper presents an open-source technology-based smart system to predict the irrigation requirements of a field using the sensing of ground parameters like soil moisture, soil temperature, and environmental conditions along with the weather forecast data from the Internet. The sensing nodes, involved in the ground and environmental sensing, consider soil moisture, air temperature, and relative humidity of the crop field. This mainly focused on wastage of water, which is a major concern of the modern era. It is also time-saving, allows a user to monitor environmental data for agriculture using a web browser and Email, cost-effectiveness, environmental protection, low maintenance and operating cost and efficient irrigation service. The proposed system is made up of two parts: hardware and software. The hardware consists of a Base Station Unit (BSU) and several Terminal Nodes (TNs). The software is made up of the programming of the Wi-Fi network and the system protocol. In this paper, an MQTT (Message Queue Telemetry Transportation) broker was built on the BSU and TU board.

KEYWORDS: Raspberry Pi3; Node-RED; Wemose-d1; Moisture Sensors; Valves; DHT11 Sensors.

I. INTRODUCTION

Wireless sensor networks (WSNs) are constantly used from the scientific community since the potential of ecological monitoring software composed of cost-effective possibility to construct and process all kinds of information with greater resolution, these systems are regarded as a important part of ubiquitous computing [1]. Therefore, using IoT-driven WSN platform in precision agriculture can revolutionize the information assortment in agricultural area and encourage the sought after exceptionally machine-driven agriculture method which demands intensive understanding of ecological conditions in the base level and speedy communication of the information to a distant or local server where the source of storage and process, identification of insects inside the plants, burial or hyperbolic moist, the alternative generating, and so the direction of plantation instrumentation is completed instantly (automatic propulsion apparatus such as sprinklers, foggers, valve-controlled irrigation method, and so forth is used for management irrigation, and fertilization and pest control in order to offset

the negative states forming wireless sensor in addition to actuator network (WSAN). The above system is accessible globally due to the involvement of IoT technology [2].

The fast evaluation and observation of soil moisture content of this massive area is necessary so that optimum irrigation will be possible in the agriculture plantation region. The gravimetric method is called the standard to determine soil water content version, but it is not effective in providing large-scale fast data collection and can be limited to a compact dimension quantity. Within exactly the same circumstance, wireless sensor network (WSN)-based land soil moisture content evaluation can be utilized for real-time observation and evaluation of dirt soil moisture content dynamics throughout the whole cropping time.

The rest of this paper is organized as follows. SectionII presents a description of the related works, SectionIII presents the proposed system for smart agriculture, SectionIV presents the protocols of Base Station Unit (BSU) and Terminal Units (TU), SectionV presents the results and



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discussion of the proposed method, Finally, Section VI concludes of the paper.

II. RELATED WORKS

In this section, we review relevant research covering coordinate control strategies in the context of areas related to this work. In 2008 Kim, et. al.[3] proposed efficient water management based on the distributed wireless sensor network for cropping systems. This system was electronically controlled by a programming logic controller that updates the geo-referenced location of the sprinkler from the differential global positioning system and wirelessly communicates with a computer at the base station. In 2013 Wang et al. [4] introduce an agricultural-cloud based greenhouse monitoring system to monitor environmental parameters in the greenhouse. This system includes a sensor node based on MSP430F1611 and a gateway based on the Intel Wind River software license. It is an Machine-to-Machine (M2M) smart services developer kit, which is a powerful Intel Atom-based processor and supports 802.11 WLAN (wireless local area network) and 802.15.4 WPAN (wireless personal area network). The system also includes an agricultural cloud application for data storing and analyzing. The system could provide more services, such as online inquiry and instant feedback. In 2014, Goyal et al. [5] present a ZigBee based real-time controller with ZigBee transmitter to transfer environment information to a personal computer via Zigbee receiver. In 2015, N. Agrawal and S. Singhal [6] designed smart drip irrigation system using Raspberry Pi and Arduino for a home automation system, Arduino microcontrollers were used to receive the on/off commands from the raspberry pi using ZigBee protocol. This smart drip irrigation system proves to be a useful system as it automates and regulates the watering without any manual intervention. In 2016, K. K. Namala et al. [7] proposed intelligent and smart Irrigation system which used for controlling the watering or irrigation of flowering plants. It controls the irrigation of plants automatically. Raspberry Pi used in the design of the prototype model in making the system compact and sustainable. The system has a sensor which measures the moisture of the soil and switches relay which controls solenoid valve according to the requirement. The model demonstrated gave expected results at the different moisture levels. Recent technological advances lead to the development of small sensor, data storage, and communication, provide advantages in cost, size, power and flexibility.

In this paper, we propose a network solution in the domain of IoT connecting the rural region with various agricultural and farming applications. In summary, the primary contributions of this paper are as follows.

1. We introduce Wi-Fi network in the existing WSN-based solutions for covering longer range with lesser delay.

2. A cross-layer-based MQTT (Message Queue Telemetry Transportation) protocol and routing solution that adapts traffic nature and sets the duty cycle accordingly to improve delay and throughput performances over multihop IoT is proposed.
3. We discuss the testbed evaluation processes and analyze the performance of the proposed architecture.

The proposed system includes two main parts, Base Station Unit (BSU) and Terminal Units (TUs). At TU, a microcontroller with a Wi-Fi module and the various sensor will be used to collect environment information. At the receiving side, a BSU device will be used to monitor sensed parameters. In this system develop a WSN system that has the following features:

- 1) low cost using open-source hardware and software.
- 2) easy to use and deploy.
- 3) expected to operate for a long time period.

III. PROPOSED NETWORK FOR SMART AGRICULTURE

The proposed architecture is a practical and promising solution for connecting rural farms using IoT with low cost. The suggested method is determined by establishing wireless sensors in the farm to acquire real-time observation and evaluate soil moisture content in the test site. The distributed sensor network nodes are utilized to acquire real-time soil as well as environmental parameters. The general parameters considered are soil moisture content, soil temperature, the temperature of the surrounding, the humidity level of the surrounding. The WSN environment is configured as Four numbers of wireless sensor nodes and a single gateway node or the coordinator node (BSU). The gateway node is also called the coordinator node and others behave as router nodes. The coordinator node is responsible to collect all the sensor information and forward it to the cloud platform for the necessary prediction of soil water requirements. The coordinator node is designed with Raspberry Pi3 and Wi-Fi using the MQTT (Message Queue Telemetry Transportation) protocol. Further, the gateway node connects the internet application via the Wi-Fi network for the prediction of the soil water requirements. The essential data set is obtained over Wi-Fi connectivity to the internet server unit for the estimation of soil Moisture Content (MC). Further, it is used to obtain the soil moisture content distribution map of the land. With this work structural based soil moisture content deficiency is calculated to manipulate irrigation valves to maintain the required water content uniform over the farm area. Fig. (1) illustrates the proposed system architecture.

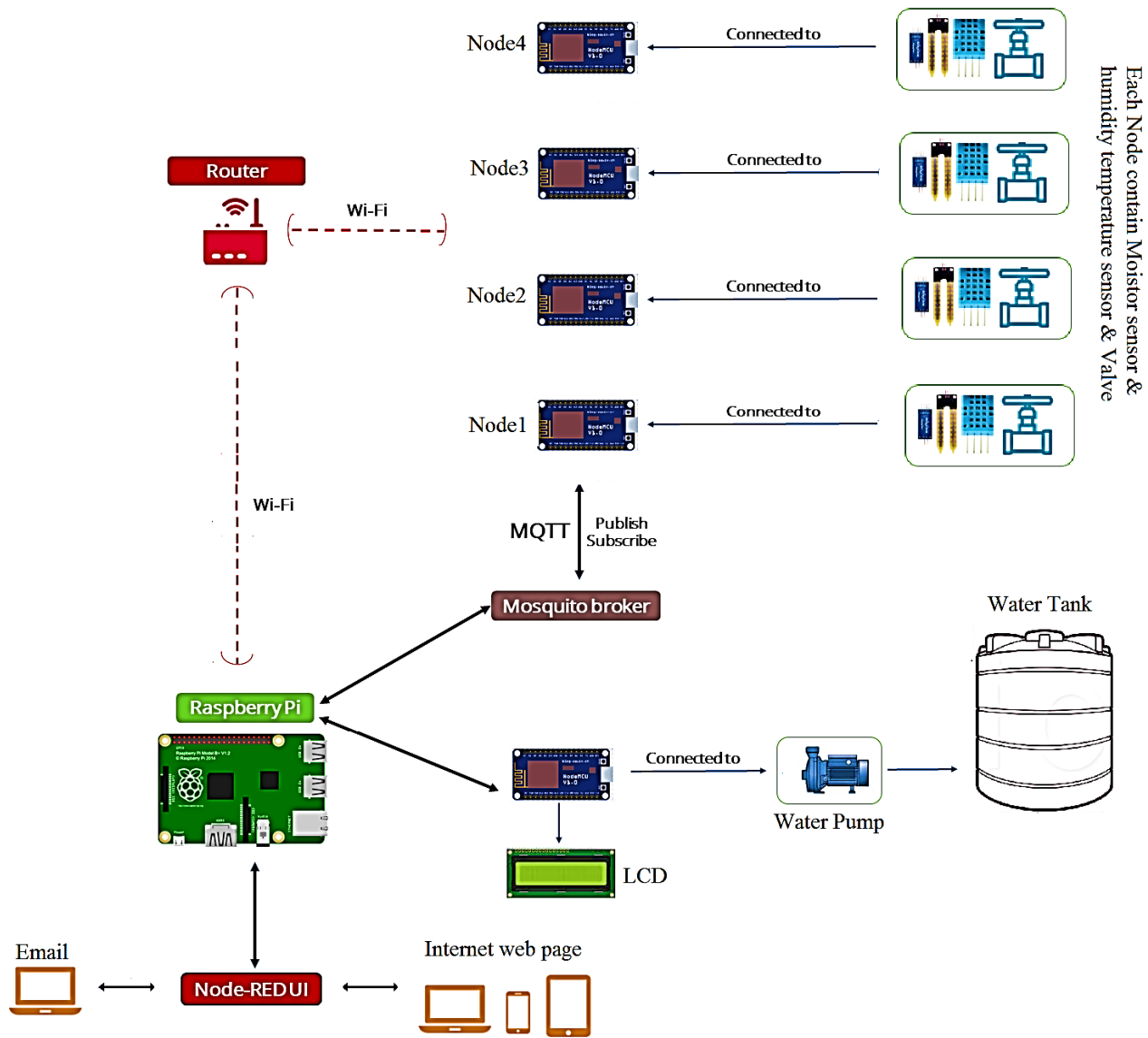


Fig. 1: Proposed smart irrigation system

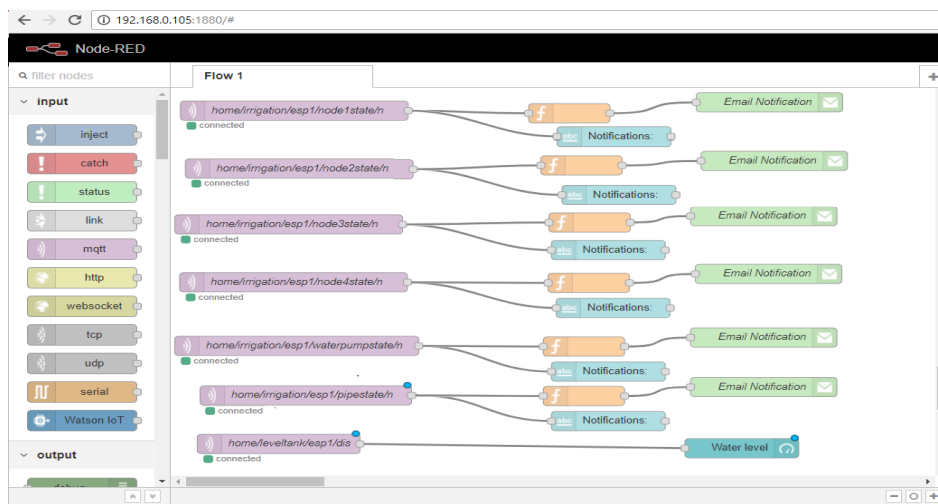


Fig. 2: The Node-Red for irrigation system

A. Base Station Unit (BSU) for Smart Irrigation

The BSU plays a key role in the designed system. In this system, has been using Raspberry pi3 (running Raspbian OS) for designing IoT BSU, which is responsible for storing, analyzing and transmitting sensor node data to the cloud. Set up the BSU into the access point mode to establish the Wi-Fi connection with the TUs can connect to. In the BSU, also installed the Elips Mosquito- an open-source message broker that implements the MQTT protocol. MQTT provides a lightweight method of carrying out messaging using a publish/subscribe model. Utilized the Node-Red platform to program the BSU. It is installed in Raspbian OS by default.

In our network, the BSU will send the command to all TUs for requiring data. Then each TU publishes its data to the specific topic in the MQTT broker, and the BSU subscribes all TUs topic to receive all data from TUs. The received data are then processed to transmit to the web page. Fig. (2) shows the node-red code. The BSU represented by a Wemose-d1 and the server Raspberry pi3, liquid crystal display (LCD). Fig. (3) (a) shows a block diagram of the system BSU and Fig. (3) (b) shows the internal structure of BSU that used for implementing the system.

1. The Raspberry Pi3 Board

The RaspberryPi is a sequence of the credit-card-sized single-board computer. All RaspberryPi model advantages a Broadcom system on a chip (SoC), which includes an ARM-compatible CPU and an on-chip GPU. Since Raspberry Pi is actually not a microcontroller, but a small-size and fully functional computer, it offers very good computational powers. With CPU speed ranges from (700MHz_1.2GHz), and onboard RAM of 1GB, the Raspberry Pi is powerful enough for every complex control operation that would be required at nodes. Though it does not have onboard Flash Memory, an external SD card should be used with the capability from 8 to 16GB allows to store multiple programs and even images from the security camera module if needed. The Raspberry Pi could also load and run Linux Operating System from a micro SD card. The Linux OS allows the Raspberry Pi to do multitasking and provides a lot of flexibility and easiness when dealing with the real-time requirement of the system. Raspberry Pi also offers 40 general-purpose GPIO pins. Moreover, the new version of Raspberry Pi 3 Model B released in February 2016 provides built-in Wi-Fi, which reduces a lot of works and costs buying and installing a separate Wi-Fi module to microcontrollers [8,10]. Fig. (4) shows the newest version of Raspberry Pi, Raspberry Pi 3 Model B.

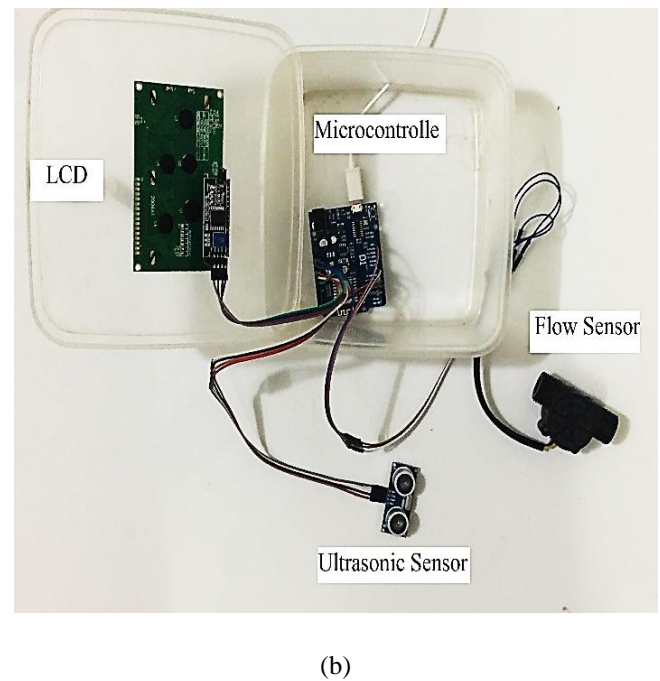
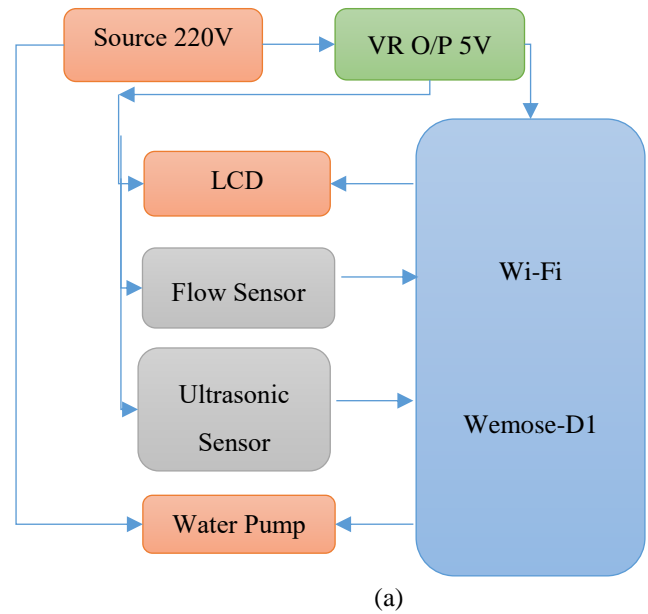


Fig. 3: (a) Show the BSU schematic diagram. (b) Show the Internal structure of the system BSU

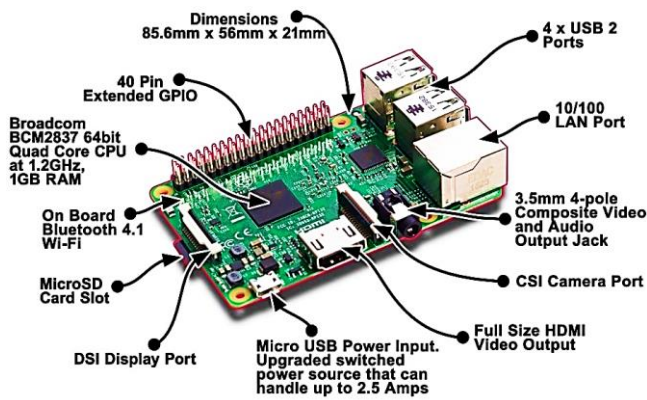


Fig. 4: Raspberry pi3 board

2. Ultrasonic Sensor

The ultrasonic sensor can sense the movement of objects. It senses motion by analyzing sound waves in its environments as the way bats or dolphins do. This could be used in our product to help detect the water level in the water tank, and send a signal to the microcontroller. Typical products for ultrasonic motion sensors have a very large detection range, around 6-7m in radius, which we valued most for the occupancy sensor. However, its main drawback is that its sensitivity could be affected by loud noise, which would affect its sound wave analyzing [11].

3. Liquid Crystal Display (LCD)

The LCD module is one of the human-machine interfaces for an embedded system. The LCD screens have been adopted in the microcontroller field to display text strings programmed by the microcontroller[12].

B. TUs for Smart Irrigation

The TU is the basic unit of the WSN system. TU comprises the sensor, processor, wireless communication module and power model. The TUs are the system responsible for the measurement of moisture, temperature and humidity depending on the sensors in the node. The soil moisture sensor used for detecting the water content in the frame soil and The DHT-11 sensor is used for sensing the surrounding air temperature and relative humidity in the agriculture field. Also, the node contains a solenoid is used to be the actuator for controlling the water flow to start or stop the irrigation process to plants according to the control signals of the TUs, which received from the BSU. Fig. (3) shows the sensor hardware structure. The processor is responsible for collecting data from sensors implementation network protocol and transmitting data to BSU. The wireless communication communicates with BSU to receive control command and send the sensors data. Each TU can be powered by 5v dc adapter. Also, each TU consists of the main unit that represented by a Wemos-d1 board, moisture sensor, humidity temperature sensor, and solenoid valve.

Fig. (3) (a) shows a schematic diagram of the system node, Fig. (5) (b) shows the internal structure of the node that used for implementing the system.

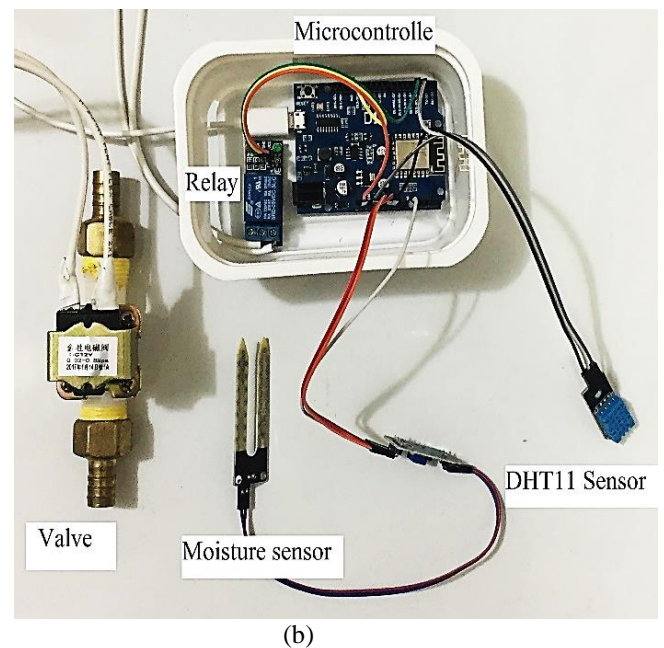
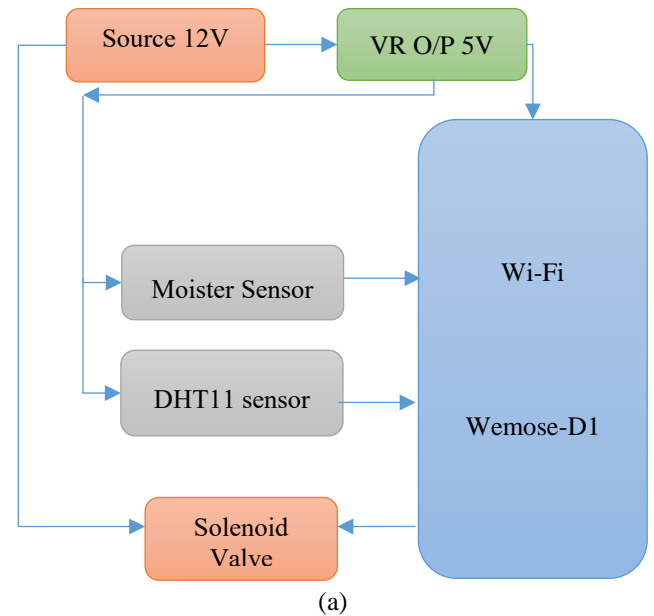


Fig. 5: (a) The Schematic diagram of TU, (b) The internal structure of TU.

The analog output of the moister sensor is an amount between two probes of the moister sensor. In this work, the analog output is used to be an analog input to the Wemose-d1 board. Since the ESP8266 microcontroller used for the Wemose-d1 contains an on-board 10 bit 1-channel analog-to-digital (A/D) converter, the analog input pin of Wemose-d1 can read analog signals being sent from the sensor and return binary integers from 0 to 1023.

In this work, has been utilized Wemos-D1 platform in the development of sensor node hardware. The platform provides an integrated development environment (IDE) that can run on all popular operating systems and has support for C/C++ programming language.

1. Microcontroller Wemose-d1 Board

Wemose-d1 board is high-performance open-source microcontroller boards based on flexible, easy to employ software and hardware. The language is C. Wemose-D1 board is built with an ESP8266 microcontroller. It consists of 14 input/output digital pins, 1 analog input, 1K Bytes EEPROM, 2K bytes SRAM, 32K bytes ISP flash memory, 80 MHz crystal oscillator, serial communication UART represented in pin 0 (RX) and pin 1 (TX), SPI serial port defined in GPIO10 which represents select slave (SS) GPIO, GPIO11 which is the master out slave in (MOSI) GPIO, GPIO12 specified to the master in slave out (MISO) GPIO and GPIO13 is the serial clock (SCK) GPIO. The Wemos-d1 board can be powered through the USB connector, AC to DC adapter or using the battery.

Also, Wemose-d1 is a great platform for any smart home system. Can create an MQTT (Message Queue Telemetry Transportation) communication, control outputs, read inputs and interrupts [13][14][15]. The Wemose-d1 pins matching to the ESP8266 microcontroller pins is shown in Fig. (6).

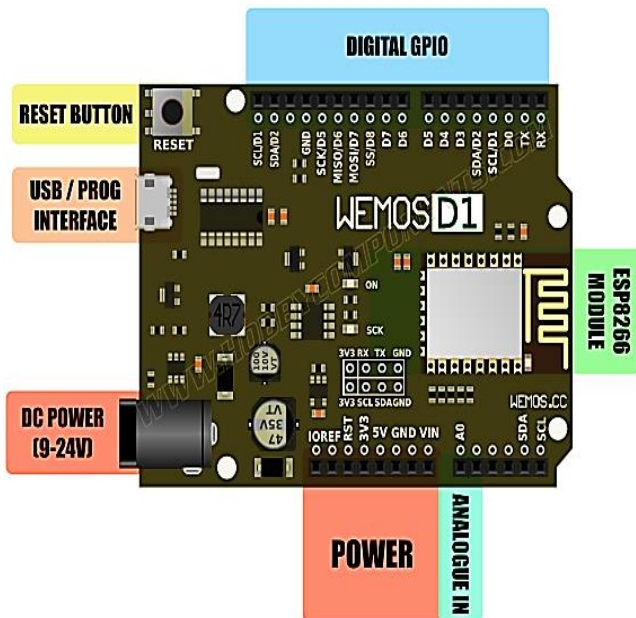


Fig. 6: The Wemose-d1 Board [15].

2. Humidity and Temperature Sensor Interfacing

It is a combined temperature and humidity sensor called DHT-11 used for sensing surrounding humidity and temperature. It's a capacitive humidity sensing. Application of a dedicated digital modules collection technology and the humidity and temperature sensing technology, to ensure that the product has excellent long term stability and high reliability [16].

3. Moisture Soil Sensor

The moisture sensor is used to sensing the soil water content in the farming field. The moisture sensor has two probes and uses them to measure soil moisture in the soil by telling how well an electrical current is passed between the two probes. The probes (electrodes) will directly contact with the ground. The more moisture in the soil gives better conductivity or lowers the electrical resistance[17].

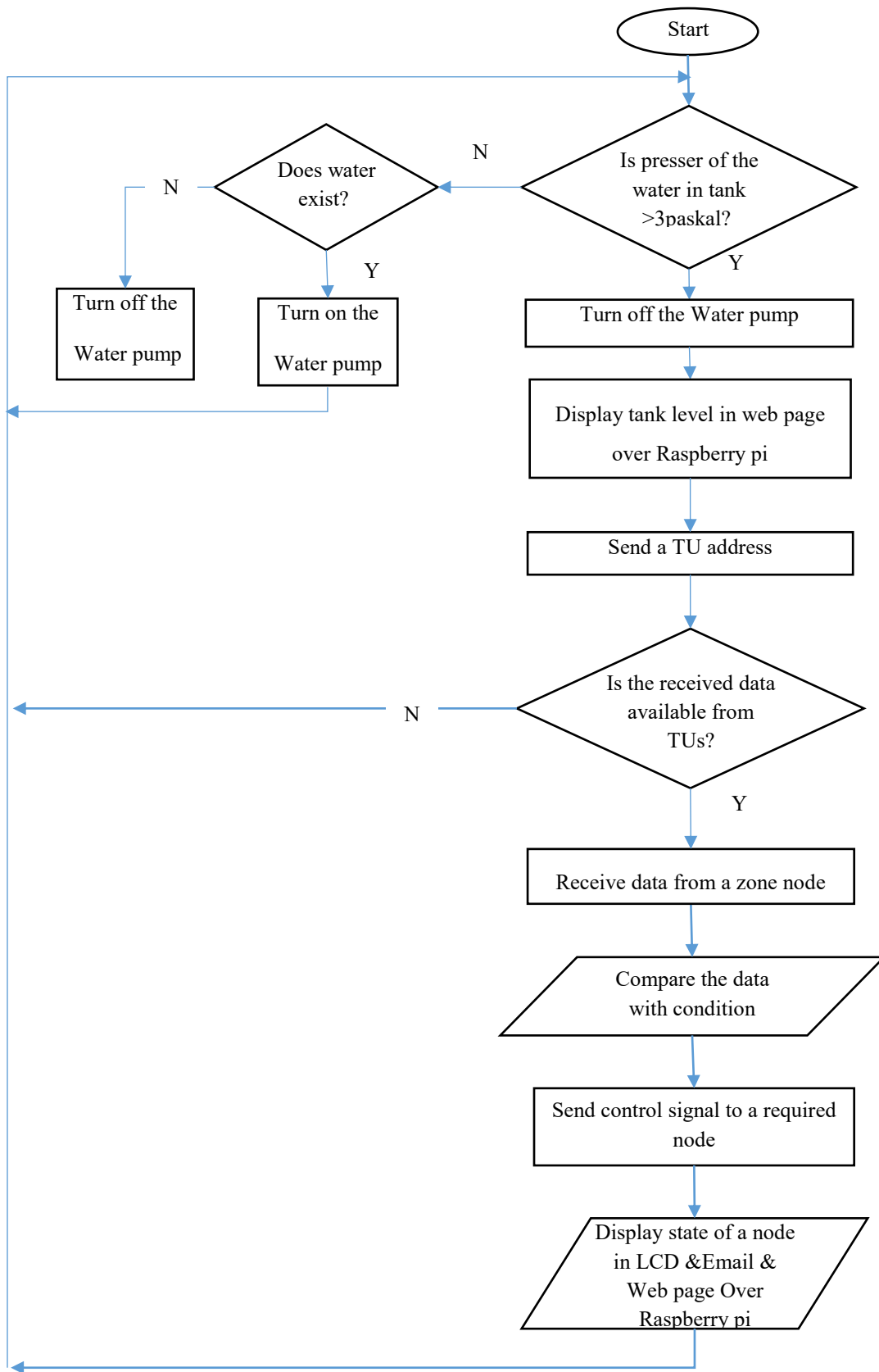
4. Solenoid Valve

This solenoid valve is used for allowing and preventing the water flow in the irrigation process.

Description: Four external diameter of thread 20mm/0.78", The inner diameter 14mm/0.55", Size L x W x H/80 x 35 x 55mm/3.14 x 1.37 x 2.16", Fluid Temperature 0-90°C, Pressure 0.02- 0.8Mpa, Rated Power 5W, Voltage DC12V, Material Metal + Plastic, threaded inlet and outlet 3/4, Ampere 300 mA, pressure required 3 PSI minimum[18].

IV. THE PROTOCOL OF BSU AND TU

The Base Station Unit (BSU) flowchart of the system BSU is shown in Fig. (7) (a). The Terminal Unit (TU) can be considered the fundamental device in the system performance. It is the system unit responsible for sensing the required parameters that the desired system operation depends on it. It senses the soil moisture, humidity and temperature, then sends these parameters with the TU address to the BSU. The TU flowchart is shown in Fig. (7) (b).



(a)

Fig. 7: (a) The BSU flowchart. (b) The TU flowchart

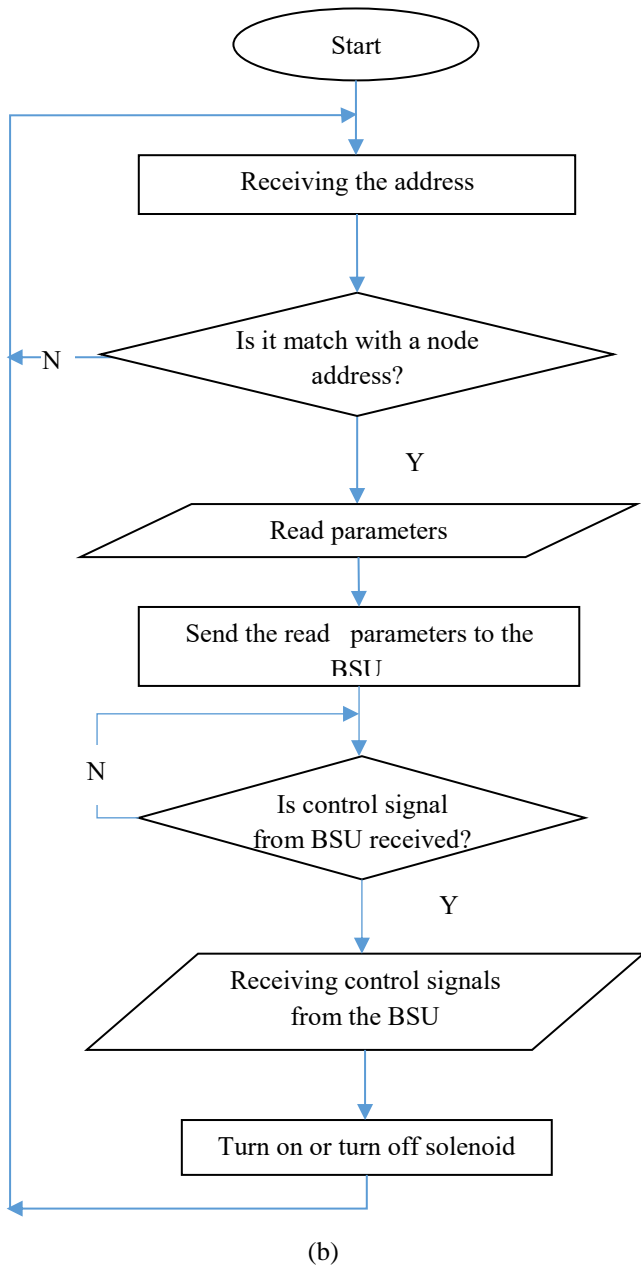


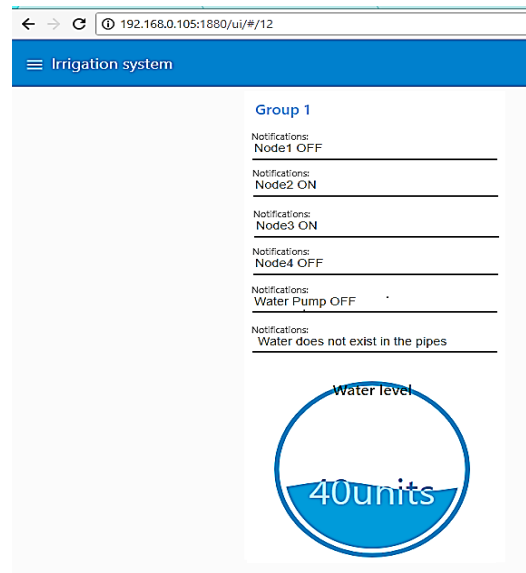
Fig. 7: Continued.

V. RESULTS AND DISCUSSION

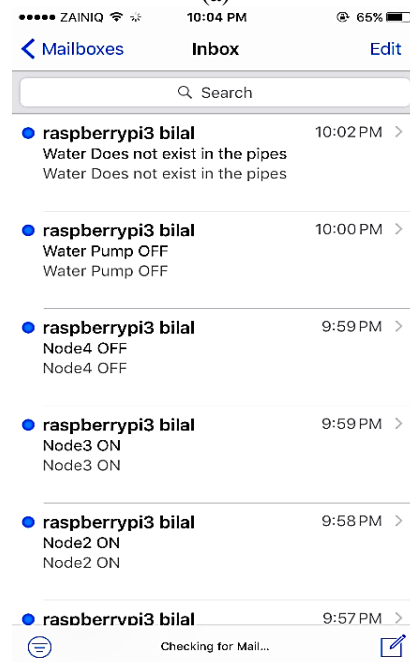
In the practical implementation of the system four TUs have been used. The smart irrigation system was tested using Anvil's plants. For a testing system shown in Fig.(8), each node connected to a soil moisture sensor, DHT11 sensor. this node is powered by adapter 5v dc. Fig. (9) shows displays the states of nodes, the water level in the tank, water exists in the pipe, and the water pump over Fig. (9) (a) web page, Fig. (9) (b) email. Fig. (10) shows displays the state of nodes and the water pump.



Fig. 8: System four nodes in anvil's plants



(a)



(b)

Fig. 9: Displays the states of nodes, the water level in the tank, water exists in the pipe, and the water pump over (a) web page, (b) email

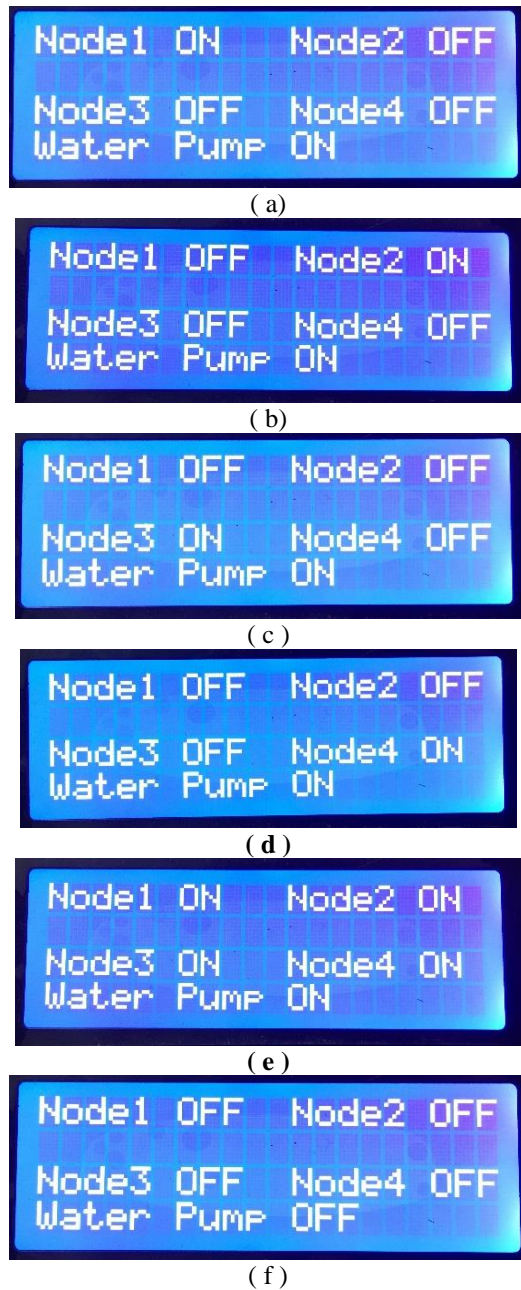


Fig. 10: Displays the state of nodes and the water pump

It can be seen from Fig. (10), that the LCD displays the state of four nodes and the water pump. Fig. (10) (a) indicate that the state of the node and water pump on and others node are off. Fig. (10) (b) indicates that the state of the second node and water pump on and other nodes are off. Fig. (10) (c) indicates that the state of the third node and water pump on and other nodes are off. Fig. (10), (d) indicates that the state of the fourth node and water pump on and other nodes are off. Fig. (10), (e) indicates that the state of all nodes and water pumps on. Fig. (10), (f) indicates that the state of all node and water pump off.

In the experiment, the system is tested through 12 hours as shown in Fig. (11).

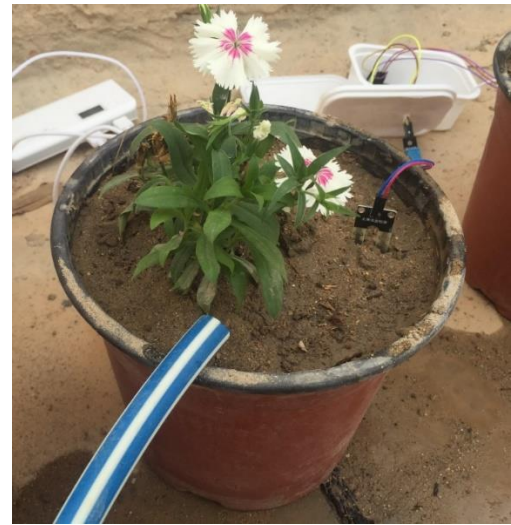


Fig. 11: System first node

In the first node, the test has been started at eight o'clock AM as shown in Table3. The soil moisture sensor read 900, and according to the irrigation conditions (the soil moisture greater than 750, the relative humidity less than 80% and the temperature greater than 15C°) the node started the irrigation process

TABLE I
THE EXPERIMENTAL RESULTS OF THE FIRST
NODE

Time	Moisture Sensor	Humidity	Temperature	Node State
8 AM	900	25.3 %	29.4 C ⁰	ON
9 AM	600	23.2 %	30.5 C ⁰	OFF
10 AM	650	21.7 %	33.2 C ⁰	OFF
11 AM	700	20.2 %	35.7 C ⁰	OFF
12 AM	850	19.6 %	36.3 C ⁰	ON
1 PM	500	18.3 %	37.6 C ⁰	OFF
2 PM	575	17.5 %	39.5 C ⁰	OFF
3 PM	625	17.0 %	40.7 C ⁰	OFF
4 PM	675	16.5 %	39.6 C ⁰	OFF
5 PM	720	19.2 %	37.2 C ⁰	OFF
6 PM	740	20.0 %	36.0 C ⁰	OFF
7 PM	785	21.2 %	34.1 C ⁰	ON

VI. CONCLUSION

This paper has presented an Internet of Things based control system for advancement in agriculture and farming of rural areas. The proposed approaches use four sensors soil moisture sensor, four humidity sensor, four temperature sensor and four valves for better efficiency. The proposed approach uses an intelligent method to decide the watering quantity and schedule of a plant considering plant type, weather conditions, soil moisture level, humidity, temperature, etc. The proposed approach focuses on efficient energy consumption as it does not turn ON all the sensors all the time. The sensors are periodically turned ON and turned OFF as needed. An intelligent algorithm handles the efficient utilization of sensors to ensure efficient energy consumption

and to keep the operating cost of this system low. The results of this study are easy to reproduce as the sensors used are cheap and easy to access. The study discusses in this paper was tested on a small area but the results of the experiments show that the used approach can be generalized and can be used for efficient irrigation of large size fields.

CONFLICT OF INTEREST

The authors have no conflict of relevant interest to this article.

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