Automatically Maintain Climatic Conditions inside Agricultural Greenhouses

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ABSTRACT

In this work, a novel system is designed to remote monitor / automatic control of the temperature, humidity and soil moisture of the agricultural greenhouses. In the proposed system, the author used the mentioned sensors for monitoring the climatic conditions of the agricultural greenhouses; and the system makes a controlling process to fix the required parameters for plant growth by running / stopping the fan, air exchanger and irrigation devices when any changes happened in these parameters. The presented system is based on XBee protocol in the implemented wireless sensor star topology network (WSN) to monitor the agricultural greenhouses in real time, and used the GSM and Internet technologies to monitor the agricultural greenhouses from anywhere.

Key words: agricultural greenhouse, xbee, wsn, gsm, internet.

المحافظة تلقائيا على الظروف المناخية داخل البيوت الزراعية

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الخلاصة

في هذا العمل، تم تصميم نِظامٍ جديد لمُراقبة الظروف المناخية داخل البيوت الزراعية عن بُعد والتحكم تلقائيا بدرجة الحرارة، الرطوبة ورطوبة التربة. حيثُ أُستخدمت في النِظام المُقترح المُتحسِسات المُشار اليها لمُراقبة الظروف المناخية للبيوت الزراعية، وكذلك فأن النِظام يقوم بعملية تحكم لتثبيت النسب المطلوبة لنمو النباتات عن طريق تشغيل / إطفاء المراوح، مُبادلات الهواء واجهزة ري المياه عند حدوث أي تغيير في تلك النسب. النِظام المُقدم اعتمد على اكسبي بروتوكول في شبكة الاستشعار اللاسلكية المُنفذة ببُنية نجمية لمُراقبة البيوت الزراعية بالوقت الحقيقي واستخدم تقنيات النظام العالمي للاتصالات المتنقلة والانترنت لمُتابعة البيوت الزُجاجية الزراعية من أي مكان.

الكلمات الرئيسية: البيوت الزراعية، اكسبي، شبكة الاستشعار اللاسلكية، النظام العالمي للاتصالات المتنقلة، الانترنت.

1. INTRODUCTION

The climatic conditions are affecting the growth of plants such as temperature, humidity and soil moisture, thus affecting the productivity especially in the area that has harsh environmental phenomena, **Vu Minh, et al., 2011**.

The agricultural greenhouse resolved these problems, where it is made from the glass or plastic that protects the plants from the harsh environmental phenomena and controls the climatic conditions inside it, **Asolkar and Bhadade, 2015**.

The greenhouse that is controlled manually by the farmers is inefficient because some plants can be impossible to growth, **Nagesh, 2015**. Therefore, in this work the author designed an automatic monitor / control system of the agricultural greenhouse to solve these problems.

Because the wireless sensor networks (WSNs) have many characteristics such as low power and low cost, they are used in many applications and the agricultural field is one of them, where it has great interest recently from both academia and industry, **Erazo, 2015**.

The WSNs used different communication protocols and network topologies depending on the implemented application, **Khan, 2016**. In the implemented system, a star network topology based on XBee protocol is used.

The IEEE 802.15.4 standard, called XBee protocol is a simple, low data, low power and low cost wireless communication and it is divided into open system interconnection (OSI) model layers. Where, the medium access control (MAC) and physical layer (PHY) are standardized by IEEE 802.15 (WPAN) while the higher layers are standardized by ZigBee alliance, **Azmi** and **Bin, 2015**.

By combining the WSN and the GSM technologies, many advantages are obtained such as increasing the reliability in terms of the emergency cases, **Sahani, et al., 2015**.

Today, the monitoring systems can be integrated with the Internet technology to be able to monitor in remote areas, **Razzaque, et al., 2016**.

2. PROBLEM AND OBJECTIVE

The greenhouses controlled manually by the farmer have problems such as some plants can be impossible to growth and the farmer cannot be able to monitor / control large numbers of the greenhouses.

Therefore, the objective of this work is to design a remote monitoring / automatic controlling real time system of open numbers of the agricultural greenhouses, and insert the GSM and Internet services practically to make the farmer able to monitor the greenhouses from anywhere.

3. SYSTEM SPECIFICATIONS

- Portable, wireless and real time system.

- Supports alarming, GSM and Internet systems.
- Low power and low cost system.
- The designed software operates on any PC and it is easy to use.
- The PC can be removed without any effect on the controlling processes.

4. SYSTEM ARCHITECTURE

In this work, a remote monitor / automatic control system of the agricultural greenhouses is designed. The system is monitoring the temperature, humidity and soil moisture of the agricultural greenhouses; and when any changes in the rates that the agricultural greenhouses are needed the system will make the automatic processes in real time to fix the required rates.

Moreover, the system is sending a SMS notification about the alarm cases to the person in charge (farmer) phone using the GSM technology and the farmer can follow-up the agricultural greenhouses from anywhere using the Internet technology.

When any change happened in the temperature and humidity rates of the agricultural greenhouses the system will run / stop the fans and air exchangers to rebalance them, and when any change happened in the soil moisture rate the system will increase / decrease the irrigation water ratio to rebalance it, and at the same time send SMS alarm to the farmer mobile.

This system is based on the WSN under XBee protocol that send the sensed data from the agricultural greenhouses (nodes) to the monitoring station (PC) in order to enable the farmer to monitor the greenhouses remotely.

The system is designed in five parts, which are node, controlling, monitoring station, GSM and Internet parts, **Fig. 1**. These parts are explained in details in the following subsections.

4.1 Node Part

This part has four sub-parts, which are MCU, sensors, transceiver and power.

4.1.1 Micro controller unit (MCU)

In this system, the ATmega 328 MCU is used, and the platform of Arduino UNO that contains ATmega 328 MCU is selected, which has features of easy hardware implementation and open-source, **Fig. 2**.

4.1.2 Sensors

The agricultural greenhouse node has three sensors, namely temperature, humidity and soil moisture. The explanation of these sensors is shown in the following:

I. Temperature and humidity sensor:

In this system, the RHT03 digital-output sensor (**see Fig. 3**) is used to measure temperature and humidity of the agricultural greenhouse. This type of sensor has feature of excellent precision, can calibrate it, full range temperature compensated, low power and low cost. It has measuring range from -40 to 80° C of temperature and from 0 to 100% of humidity, **RHT03 Data Sheet**.

II. Soil moisture sensor:

In this system, the EC-5 analog-output sensor (**see Fig. 4**) is used to measure the soil moisture. This type of sensor has feature of excellent accuracy, is not affected by soil salinity and texture, low power and low cost. It has measuring range from 0 to 100% of soil moisture, **EC-5 Data Sheet**.

4.1.3 Transceiver

In this system, the XBee Series 2 transceiver module (**see Fig. 5**) is used to connect the agricultural greenhouses nodes with the monitoring station, where they are configured by using X-CTU program. These XBees (in agricultural greenhouse) are configured as End-Devices firmware by using AT command mode. The XBee - ZigBee (IEEE 802.15.4) protocol supports star, cluster tree and mesh network topologies; and in this work, a star topology is selected in the WSN because it provides low delay, low power and easy synchronized.

4.1.4 Power

In this system, a 9v lithium ion rechargeable battery is used in each agricultural greenhouse node; and there is a limit operation time of the node. To reduce this limitation, the author used the instruction of SLEEP_MODE_IDLE which deactivate the unnecessary MCU functions.

4.2 Controlling Part

In this system, the control processes are done automatically. When any changes in the rates that the agricultural greenhouses are needed, the system will make the automatic processes in real time to fix the required rates.

When any change happened in the temperature rate of the agricultural greenhouse, the system will run / stop the fan to rebalance it, **Fig. 6**. When any change happened in the humidity rate of the agricultural greenhouse, the system will run / stop the air exchanger to rebalance it, **Fig. 7**. When any change happened in the soil moisture rate the system will increase / decrease the irrigation water ratio to rebalance it, **Fig. 8**. Note that all control processes are done by utilizing the Power-Switch Tail II based on the MCU, **Fig. 9**.

4.3 Monitoring Station Part

This part has two sub-parts, which are gateway (GW) and computer (PC).

4.3.1 Gateway (GW)

It is a XBee S2 transceiver (**see Fig. 5**) that is used to exchange data between the agricultural greenhouses nodes and the PC in the monitoring station, where, it is programmed as a Coordinator in the designed WSN.

4.3.2 Computer (PC)

In the PC of monitoring station, the monitoring processes are done in it. Where, the national instruments laboratory virtual instrument engineering workbench (NI LABVIEW) software is used to perform these processes, because the LABVIEW has a graphical user interface (GUI) which is easy hardware interface with very low delay. **Fig. 10** shows the main GUI designed window.

4.4 GSM Part

The GSM part is used to send automatically SMS alarm to the farmer phone. This service is performed without using a GSM modem; therefore adding some characteristics to the system of being low delay, low cost and low complexity. Which is achieved by interfacing the phone with the Computer (PC) through the USB and using the SMSs AT commands to send the messages.

4.5 Internet Part

The Internet subsystem is used to follow-up the agricultural greenhouses from anywhere. It is performed by designing a special web site using the visual basic dot net (VB.NET) and active server pages dot net (ASP.NET) programs. **Fig. 11** shows the main designed web.

5. SYSTEM IMPLEMENTATION

The implemented system is supported by appropriate hardware components and software programs to perform its operations.

The designed hardware of node part and monitoring station part are shown in **Fig. 12**a, **Fig. 12b, Fig. 12c, Fig. 12d and Fig. 12e**. The software programs that used in the implemented system are classified below:

- MCUs: IDE.
- Sensors: C++.
- Transceivers: X-CTU.
- GUI Window: LABVIEW.
- GSM: AT-Commands.
- Internet: VB.NET and ASP.NET.

6. SYSTEM OPERATION

The implemented system is performed in two main operations, which are searching and sensing operations. In the searching operation, the system detects the active nodes (agricultural greenhouses) in the network. And in the sensing operation, the system reads (senses) the signals from the agricultural greenhouses to monitor their plants status.

The searching and sensing operations are performed between the GW and the END-Devices nodes based on the real time star WSN.

In each END-Device node, Xbee transceiver is used to receive the request from the GW and passed it to the MCU to process it and perform the specified operation. The Xbee END-Device transceiver sends the sensed data to the GW and then passes it again to the GUI window to process the sensed data and displays it in the specified fields.

The Coordinator (GW) is performed touring between the END-Devices in three seconds for each node. If an alarm case happens, the GUI window should play alarm tone (with indicator) to alert the user and at the same time the concerned MCU node is turn ON the buzzer and the red LED, and also send alarm message to the farmer mobile. **Fig. 13** shows a flowchart of the overall system operation.

7. RESULTS

In this section the results of the presented system will be introduced. Where, the author designed a three prototype of the agricultural greenhouses according to the available potentials.

The following results are presented according to real cases of Tomato agricultural greenhouses in the month of November, where the best Tomato environments conditions are Temperature (15 – 30 Celsius), Humidity (50 – 60 percentage) and Soil Moisture (70 – 80 percentage), **FAO Organization, 2013**.

Fig. 14a shows the result of first node; in this case, the user chose a single mode monitoring and there is no alarm case. **Fig. 14b** shows the result of second node; in this case, the user chose a multi-mode monitoring and there is an alarm case of humidity. **Fig. 14c** shows the result of third node; in this case, there is no alarm case. **Fig. 15a** shows the alarm SMS notification message that the farmer is received. **Fig. 15b** shows the alarm SMS notification message when any node is shutdown (turn off). **Fig. 16** shows the actual measured data in the designed web site.

8. CONCLUSIONS

The implemented system is a novel smart electronic system used to monitor and control the agricultural greenhouses, and the processes are done remotely in real time based on XBee protocol in the implemented star WSN.

The PC of the monitoring station can be removed without any effect on the automatically controlling processes of the fan, air exchanger and irrigation devices.

The novelty of the implemented system is reflected from being able to remote monitor / automatic control agricultural greenhouses in real time, and it is a wireless portable system; and it is supported by alarming, GSM and Internet systems. Moreover, the implemented system is used for all plants types.

All sensors were tested and compared with the calibrated instruments; and the implemented system was tested in different statuses and the measured data were found precise.

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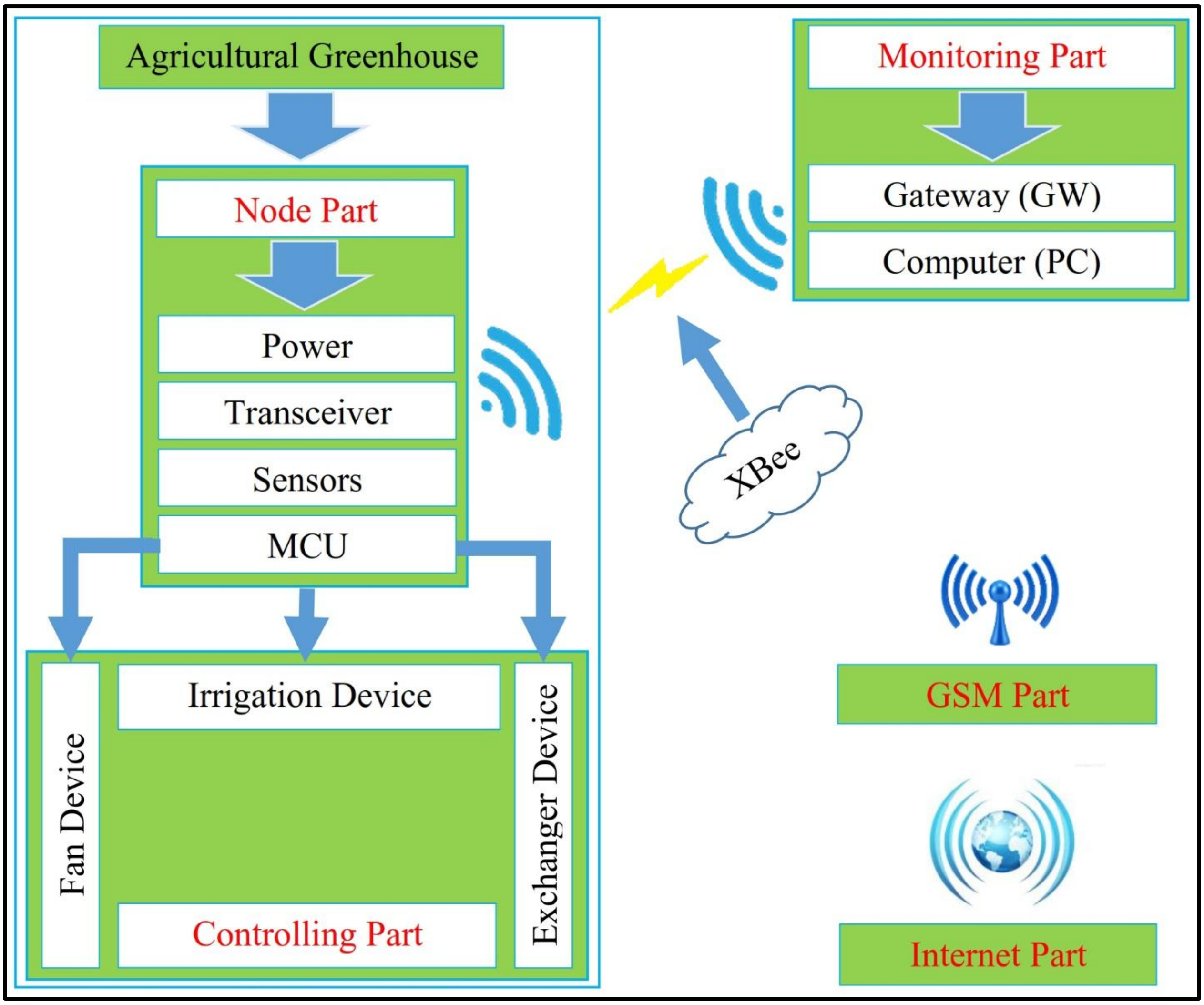

Figure 1. Overall proposed system.

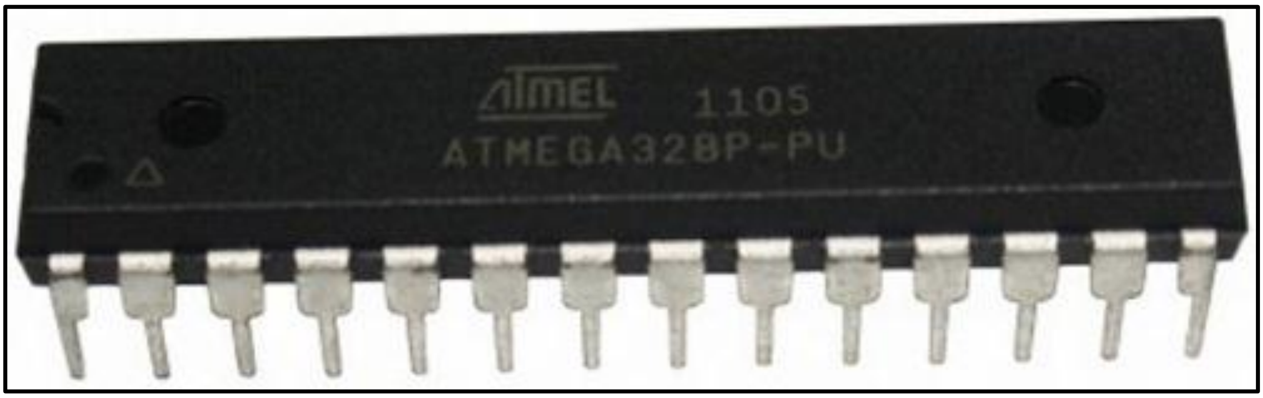

Figure 2. ATmega 328 MCU.

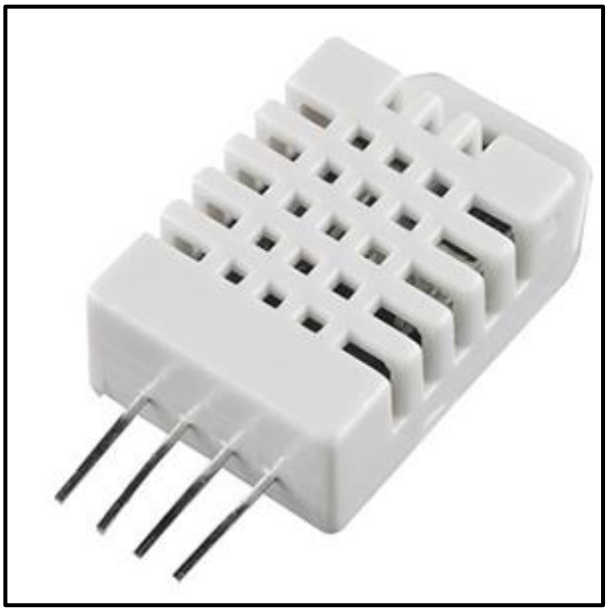

Figure 3. RHT03 sensor.

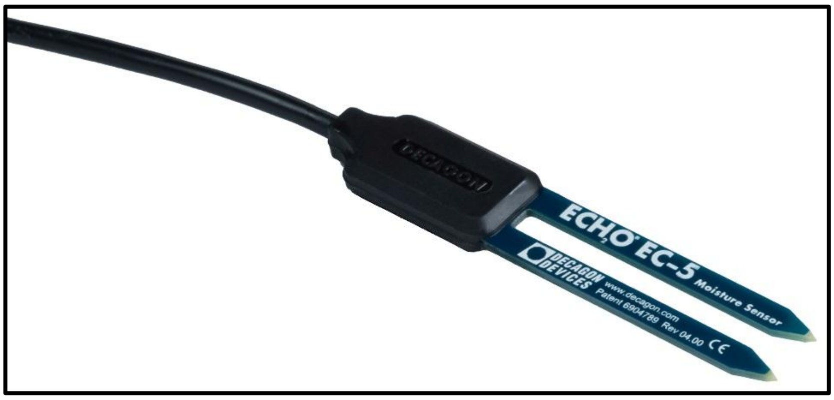

Figure 4. EC-5 sensor.

Figure 5. XBee series 2 transceiver.

Figure 6. Fan device.

Figure 7. Air exchanger device.

Figure 8. Irrigation water device.

Figure 9. Power-switch tail II.

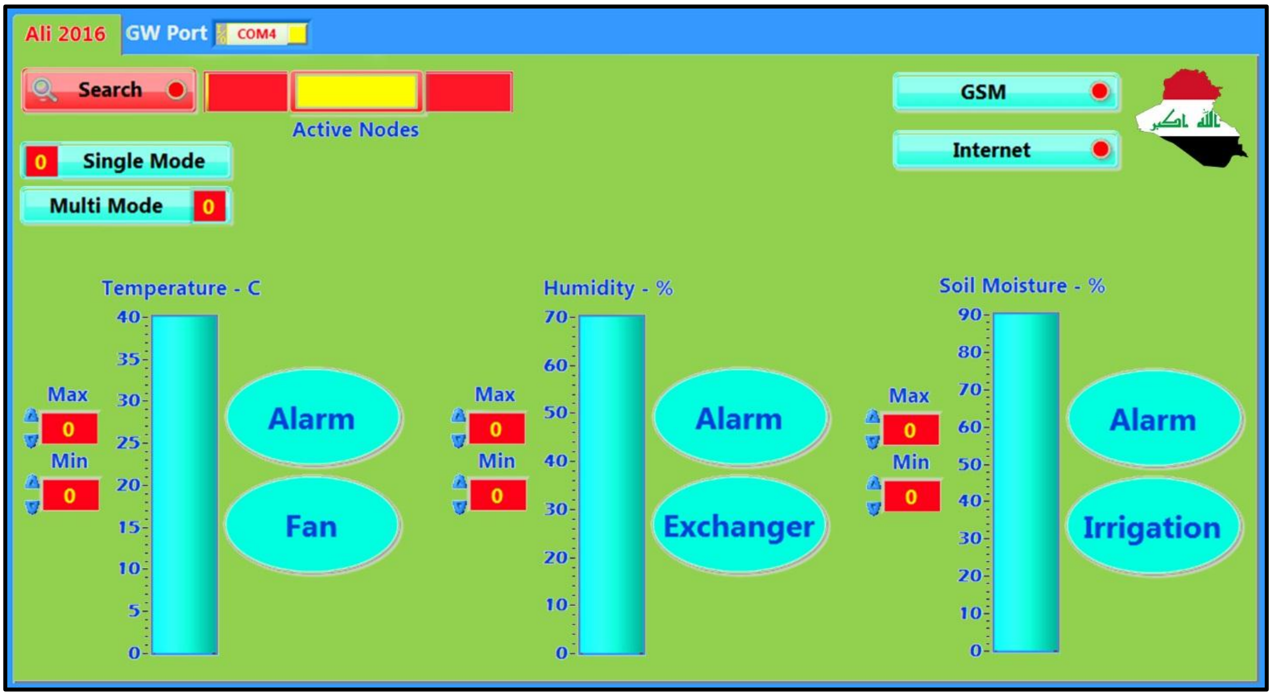

Figure 10. Main GUI window.

Figure 11. Main web site.

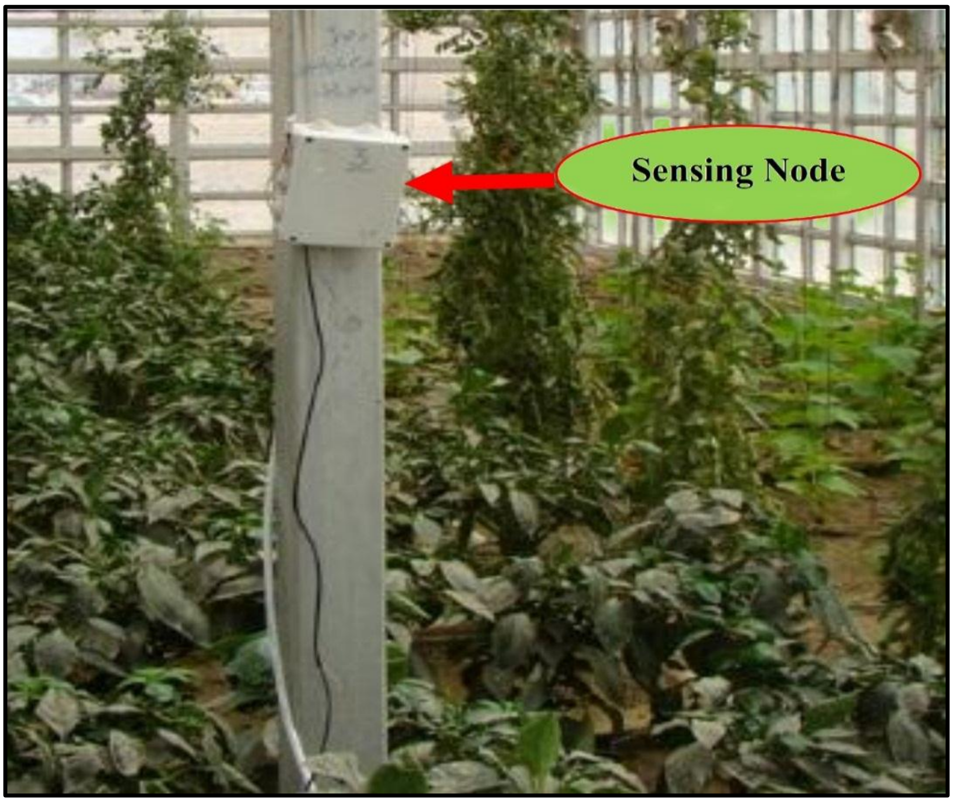

Figure 12a. Sensing node.

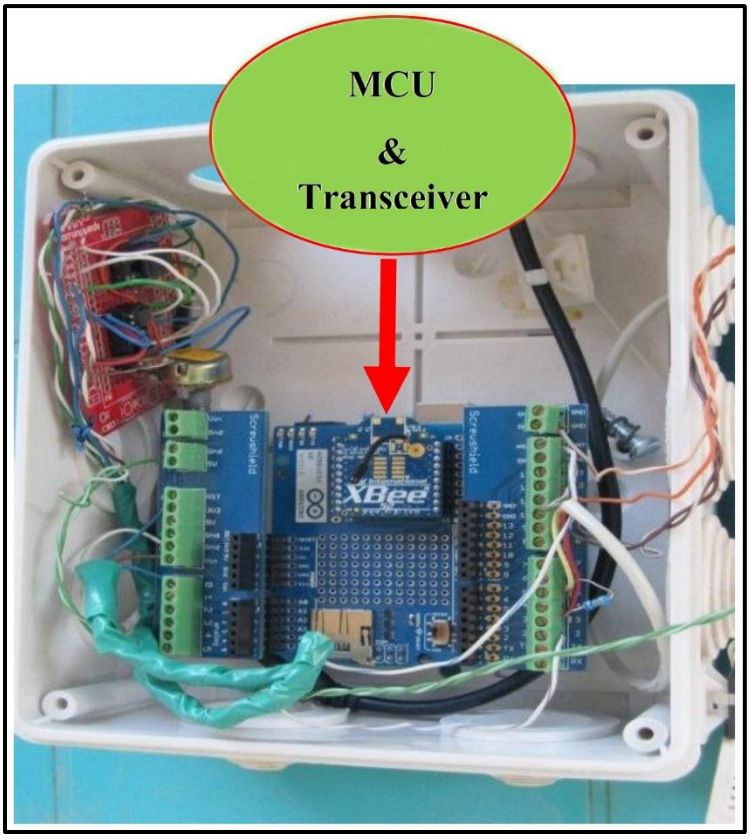

Figure 12b. MCU and transceiver of sensing node.

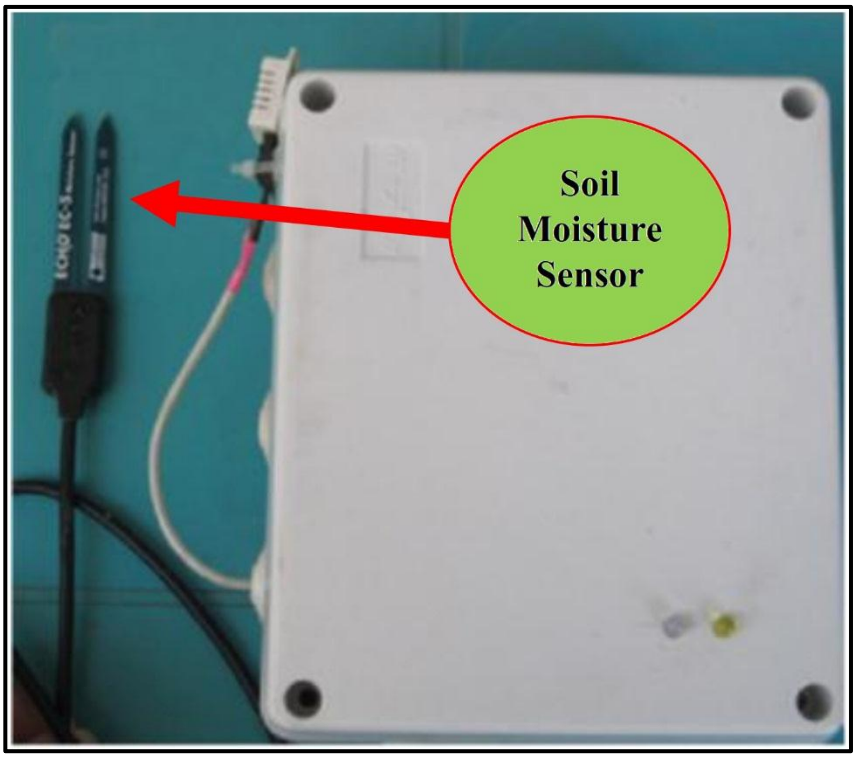

Figure 12c. Soil moisture sensor.

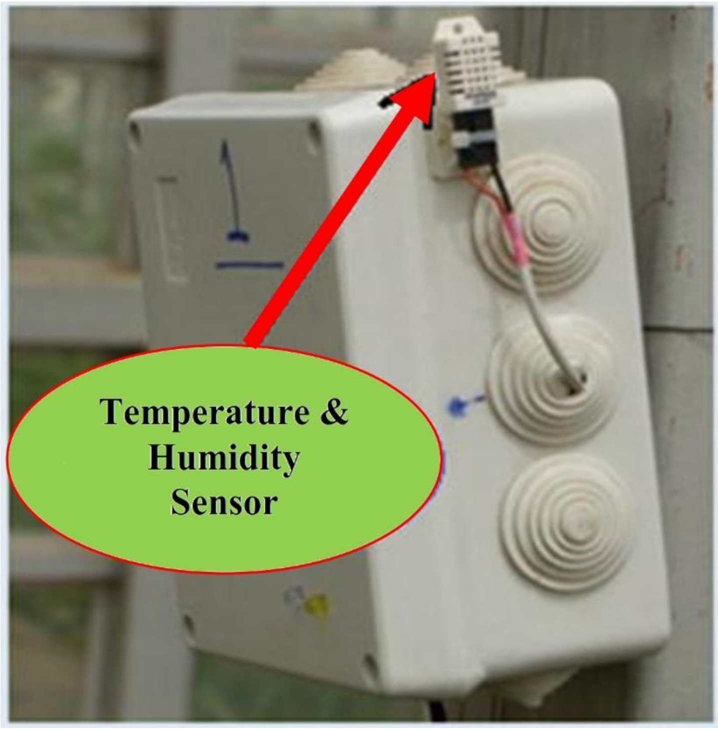

Figure 12d. Temperature sensor.

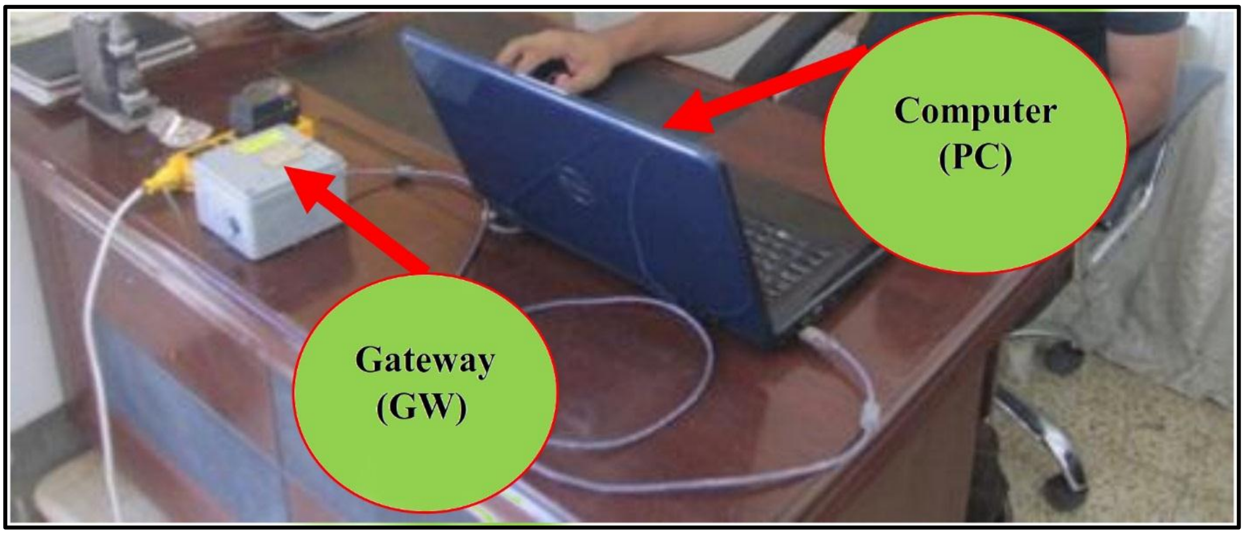

Figure 12e. Monitoring station.

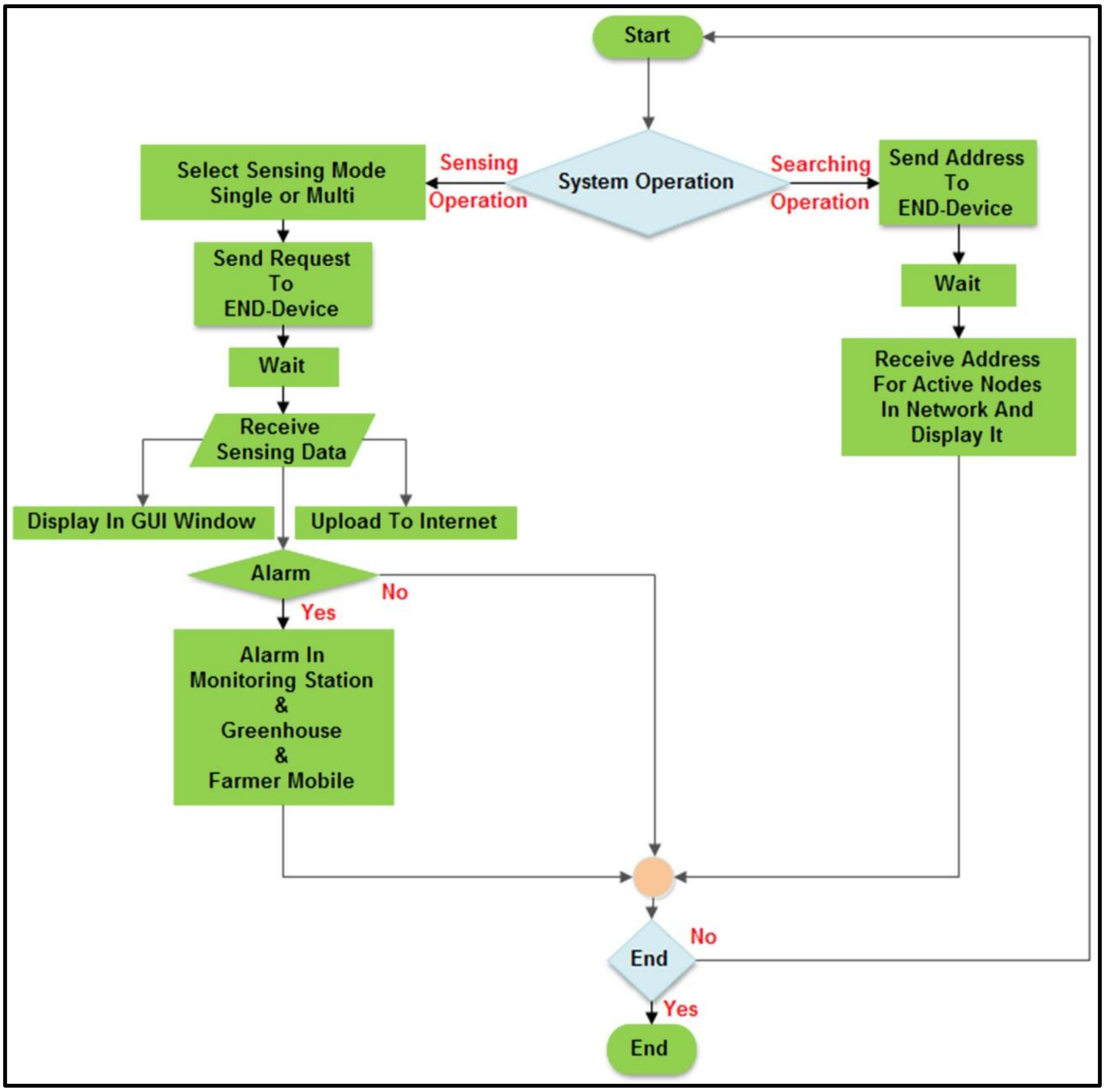

Figure 13. Overall system operation.

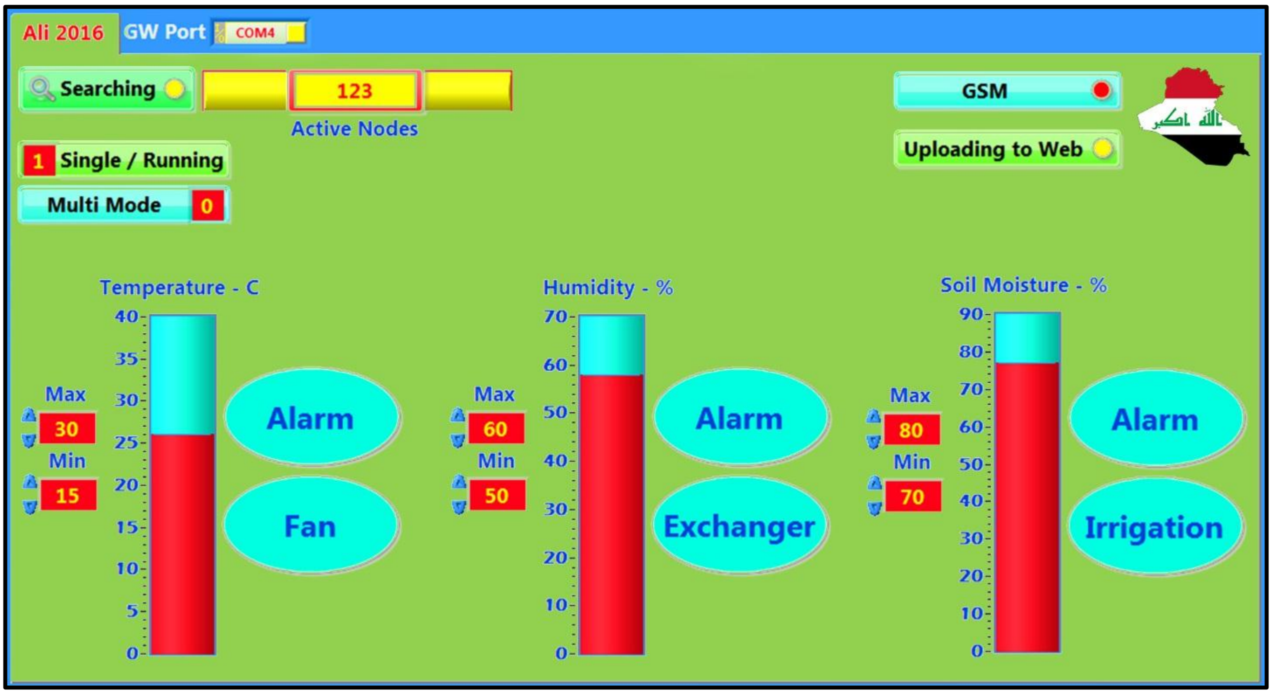

Figure 14a. Result of first node.

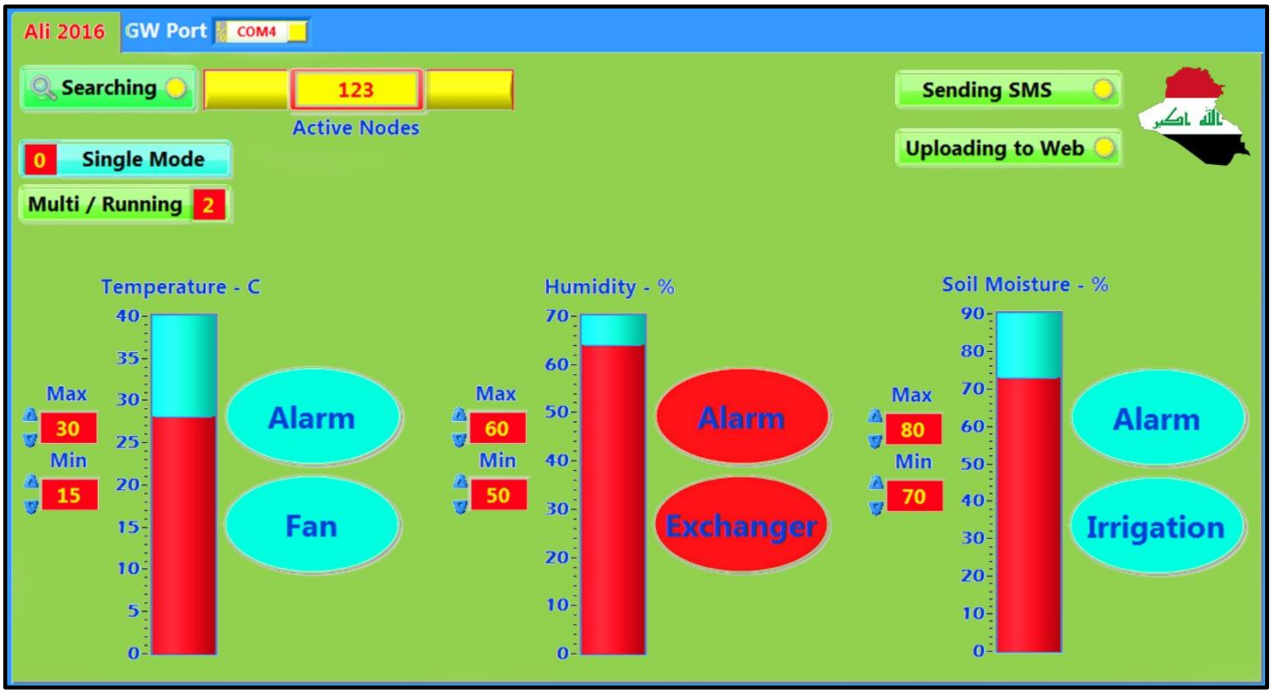

Figure 14b. Result of second node.

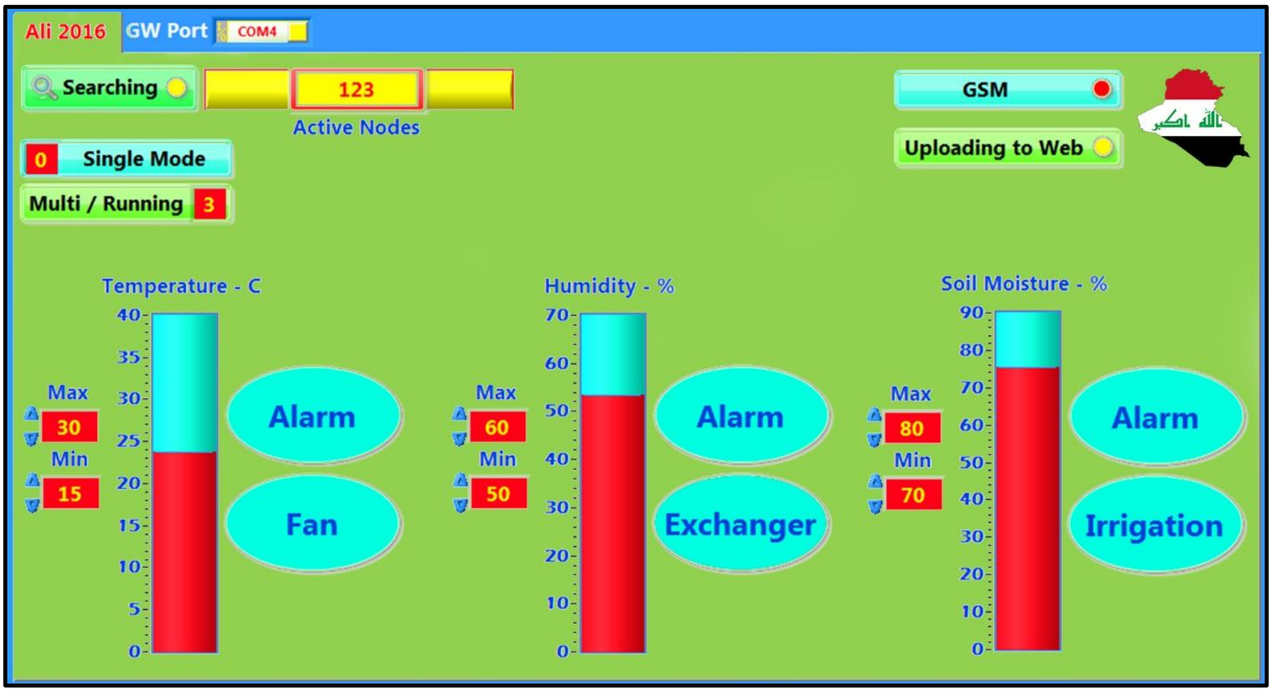

Figure 14c. Result of third node.

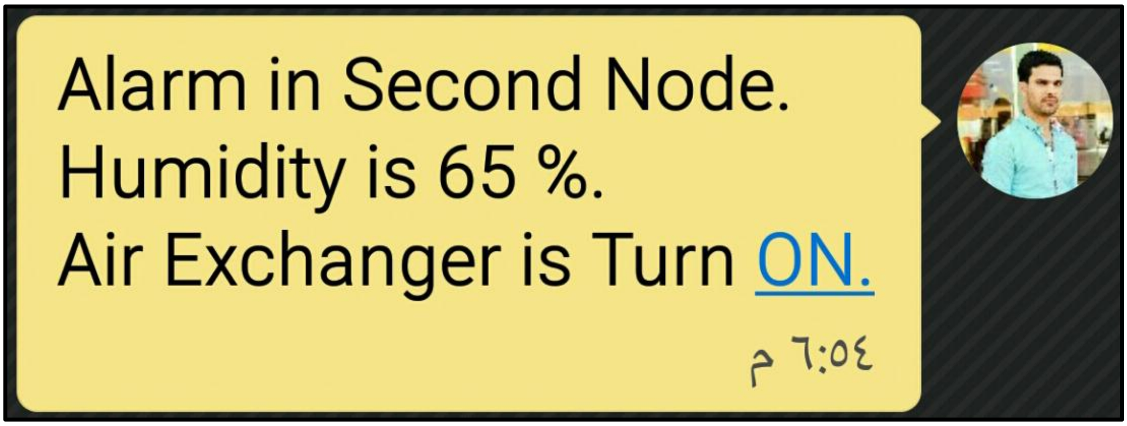

Figure 15a. SMS alarm.

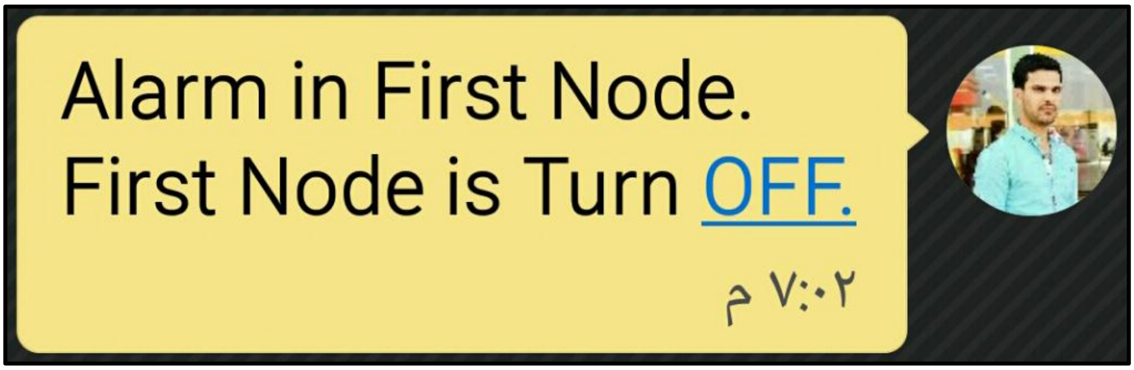

Figure 15b. SMS alarm.

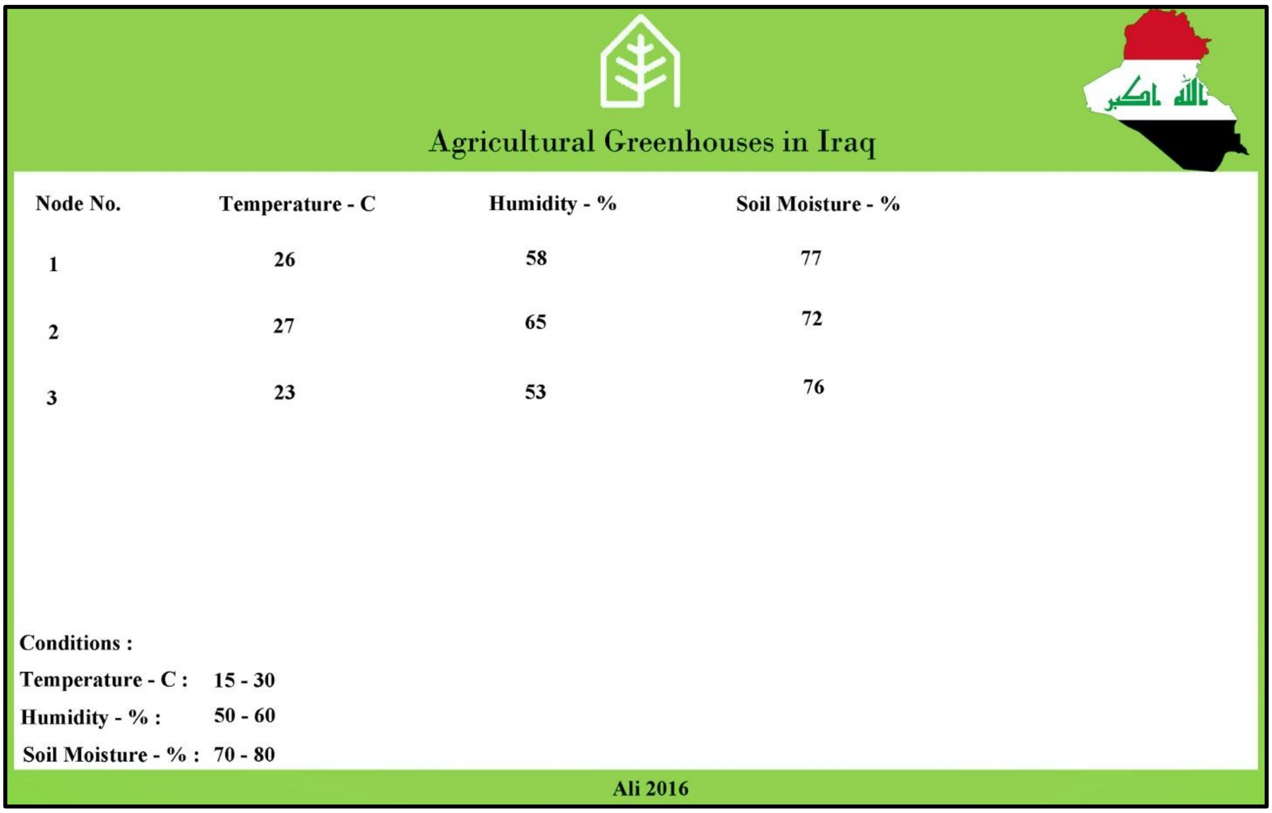

Figure 16. Result of web site.