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IMPLEMENTING SMART MONITORING ON HYDROPONIC SYSTEM USING RASPBERRY PI AND ARDUINO

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Abstract. *Hydroponics is one of planting technologies by using water media to meet the nutritional needs of plants. Water utilization in hydroponics system is more efficient compared to cultivation system using soil media. The water that has been mixed with the mineral nutrients required by the plant is continuously flowed into the roots of the plant. Another advantage of this method is very suitable to be applied in limited land such as urban home environment. Most urban activities are mostly done outside the home, like activities for work, school, shopping and others. Thus, it is seen that the observation of the hydroponics system becomes not easy to do. An example is the observation of the flow of water is the most important factor in the hydroponics system to ensure the plants get adequate supply of nutrients. Water level, water temperature, and water pH are some other factors that exist in hydroponic systems that need to be observed periodically to determine the appropriate action. This problem can be solved by developing smart monitoring based on Internet of Things technology on hydroponics system so that the observation can be done from a distance and can be reported directly through telegram instant messaging.*
Keywords: Smart monitoring, Internet of Things, Hydroponic system, Raspberry Pi

1. **Introduction.** This research is a continuation of previous research published in *Telkomnika (Telecommunication Computing Electronics and Control)*, vol.17, no.2, pp.897-906. Most urban activities are outside the home, such as work, school, and shopping. With the limited time available, the application of smart monitoring based on Internet of Things technology can provide enormous benefits. Monitoring can be done from a distance and can be accessed anytime. In addition, under certain circumstances monitoring results can be sent directly via instant messaging.

One way to improve the quality of human life in food needs is to apply the hydroponic system, which is one of the technologies to grow crops using water media to meet the nutritional needs of the plant. The water that has been mixed with the mineral nutrients required by the plant is continuously flowed into the roots of the plant. Temperature, water level, and pH of water need to be constantly observed to determine the required action.

In this research, Raspberry Pi is used, which is a credit card-sized minicomputer that can be utilized as the basis for main program development and Arduino-based Internet of Things device equipped with several sensor modules. The scope of this research will be limited to the development of hardware and software to monitor a hydroponics system by utilizing Internet of Things technology, which consists of:

1) Temperature sensor, pH and water level
2) Arduino Internet of Things module

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3) MySQL database
4) Web server
5) Telegram instant messaging

The target of development of hydroponic system device can be applied in residential environment.

2. Literature Review.

2.1. Internet of Things technology. Based on one of the existing literature on the www.internetsociety.org [1], the term of the Internet of Things (IoT) was first used in 1999 by Kevin Ashton to explain a system that can connect objects who physically looks into an Internet network by using sensors. The rapid growth of technology and the support of automation systems create a smart system that can improve human welfare [2]. IoT consists of Instrument, Interconnect, Intelligently process (3 I's) [3].

According to Jesus and Neto [4], when the sensor operates, the sensor converts a form of energy into another energy called transducer. Sensors that operate indirectly will change their properties, such as resistance, capacitance or inductance, which occur proportionately.

Here are 6 points of the application of IoT which is a combination of two large groups of Information and Analysis and Automation and Control according to an analysis from McKinsey & Company [5]:

a) Information and Analysis: Tracking behavior, enhanced situational awareness and sensor-driven decision analytics;

b) Automation and Control: Process optimization, optimized resource consumption and complex autonomous systems.

This research will focus on sensor-driven decision analytics for a hydroponics system that is in a residential setting. This is the first step to fulfil some parts of the above criteria. The Internet of Things also has been identified as one of the technologies that will emerge in IT technologies as reported in the IT Gartner Hype Cycle [6]. Buckley said, the Internet of Things may react autonomously to the real world. This is known as proactive computing [7].

2.2. Raspberry Pi overview. Raspberry Pi is a minicomputer with the size of a credit card developed by the Raspberry Pi Foundation in the United Kingdom. The device was created by a hardware architect from Broadcom named Eben Upton. This device was created with the initial goal of helping to recognize the challenges of computer basics in schools and developing countries [8].

The measurement data obtained from the temperature, pH and water level sensors in the hydroponics system is sent over the Intranet network to Raspberry Pi which functions as a web server and database server; in addition, Raspberry Pi also serves as an IoT Gateway to connect to telegram instant massaging.

2.3. Raspberry Pi architecture. Until 2015, the Raspberry Pi has 6 versions, namely: Raspberry Pi 1 Model A and Model A+, Raspberry Pi 1 Model B and Model B+, Raspberry Pi Model B 2, and the Raspberry Pi 2 Zero [9]. Raspberry Pi uses ARM Central Processing Unit Broadcom BMC2835 and a GPU that features some of the following connectors [10]:

1) General Purpose Input and Output (GPIO)
2) Display Serial Interface (DSI)

15 pin flat ribbon cable that can be connected to communicate with the LCD or OLED display.

3) Camera Serial Interface (CSI)

Port for camera connection.

4) P2 and P3 Header

This is a Broadcom proprietary header which is useful for Broadcom chip JTAG testing header (P2) and LAN9512 Networking Chip (P3).

Open Source Linux Operating System is the most widely used. By adjusting the Raspberry Pi Hardware Architecture, Raspbian is a free Operating System based on Debian suitable for general use. Raspbian currently has 35000 software packages that are easy to install, and the support of an active community to improve the stability and performance of each package [11].

2.4. **Arduino minimum system.** In accordance with the general explanation in www. arduino.cc, Arduino system is defined as a minimum that is Open Source for Hardware or Software [12]. Arduino Board can read input from the sensors installed, keystrokes until a short message via a computer network which is then processed into an output that is supported by the microprocessor on board. Arduino also provides supporting software to allow users to create Application Software by providing the Arduino programming language and Arduino IDE Software. In this study, using WiDo is an Arduino Compatible Board designed for the purposes of Internet of Things. Here are the specifications of the module WiDo v1.0 [13]: Reach resources 5v or 7-12v, Leonardo Arduino Compatible, Integrated with WG1300 WI-FI module Chip for 2.4GHz IEEE 802.11 b/g, On board PCB Antenna 2.4G and Microcontroller ATMEL ATmega32U4.

2.5. **Module sensor.** To perform pH measurements one sensor is connected to one of the analogue input pins, while the water temperature and water level are connected to the digital pins of the WiDo module. The measurement results of the three sensors are stored into the database in the Raspberry Pi module which can be accessed through the web browser on the Intranet network and telegram instant messaging through the Internet network.

2.5.1. *Temperature module sensor.* A waterproof temperature sensor DS18B20 is used to measure the water temperature present in a water reservoir of a hydroponics system. This sensor can be used from $-55°$C up to $+125°$ Celsius and has a digital output (9-12 bits) that can be programmed according to precision needs. Communication with this module uses an interface cable with a voltage of 3-5 volts DC [14].

2.5.2. *pH module sensor.* There are two kinds of pH sensor that is owned by DFRobot [13] that is low cost and industrial probe. In this research, low cost pH meter probe SKU: SEN0161 is used as the first step to identify problems in constructing a remote observation system for the hydroponics system.

2.5.3. *Water level sensor module.* Water level sensors are required to know the water reserves that are present in the hydroponic water reservoir. The workings of the ultrasonic distance sensor HC-SR04 is by measuring the travel time required by sound to bounce off objects that are in front of the sensor [15].

2.6. **Hydroponic technology.** Hydroponics is a technology to grow crops by using water media to meet the nutritional needs of plants. So, with hydroponics system we do not need soil. The water that has been mixed with the mineral nutrients required by the plants is put into a reservoir. Then this water is diverted to the roots of the plant with the help of a water pump to push it. By utilizing the force of gravity, this water will flow by itself into the reservoir of water through a predetermined path. In addition to maintaining water levels, water flow and temperature, the water pH is important to always be observed and controlled, because the plant will lose the ability to absorb the nutrients needed if the pH value does not match the characteristics of the plant. The following are some of the existing hydroponic system techniques [16]: Deep Water Culture, Nutrient Film Technique, Aeroponic, EBB and Flow and Drip System.

3. Result.

3.1. Hardware specifications. Smart monitoring on this hydroponics system using Raspberry Pi 1 Model B is the main module for storing measurement data and IoT Gateway via telegram instant messaging. Raspberry Pi has Mini Power interface, SD Card, USB, HDMI, LAN, Composite Video Output RCA, Analog Audio output Mini Stereo Sockets and GPIO Header. With the completeness of the interface owned and the ease in the development and manufacture of application programs in Raspberry Pi, the making of an electronic project becomes more attractive, efficient and effective.

3.2. Design of hardware architecture. Figure 1 below is the hardware architecture of Smart Monitoring implementation on hydroponic system using Raspberry Pi as IoT Gateway and WiDo as main controller for temperature sensor module, pH and water level.

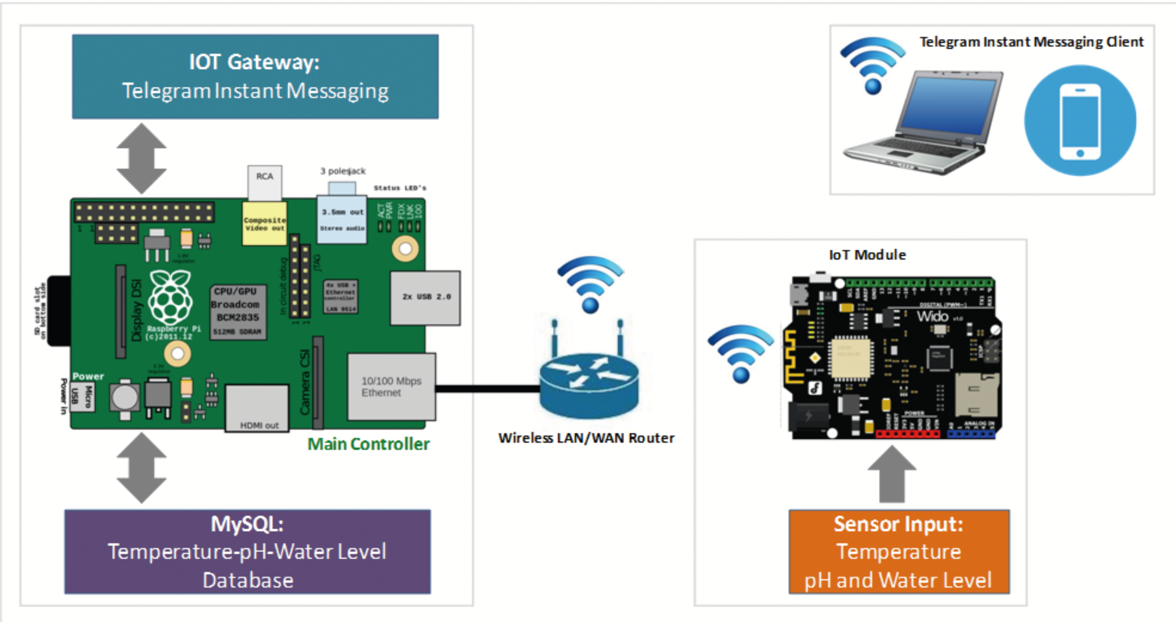

FIGURE 1. Hydroponic IoT hardware system architecture

With the above hardware architecture it allows to access the monitoring system easily from anywhere through Internet network communication channels. Monitoring can be done by giving orders through the custom menu that the author created on Telegram Bot. For usage can be via Web Telegram Instant Messaging or directly through Telegram Instant Messaging Application. All measurement data from sensors installed on the WiDo module will be stored by Raspberry Pi in the MySQL database.

Hydroponic IoT software system architecture. Shown in Figure 2 is a software architecture for smart monitoring implementation using the Internet of Things in a hydroponics system using Raspberry Pi. By using client server architecture model, most of the process will be done by Raspberry Pi as server so that the required resource on client device is small. Another advantage of this model is that the client can easily get into the hydroponic monitoring system from anywhere if the client device is connected to a wireless LAN/WAN Router that is equipped with WEP or WPA wireless security and connected to the Internet.

3.3. Hardware implementation. Raspberry Pi is placed on a box next to the wireless router (Figure 3), while IoT sensor box is placed close to a hydroponic plant cultivation. Connect to the wireless router using a Cat-5e Ethernet cable with bandwidth of 100Mbps.

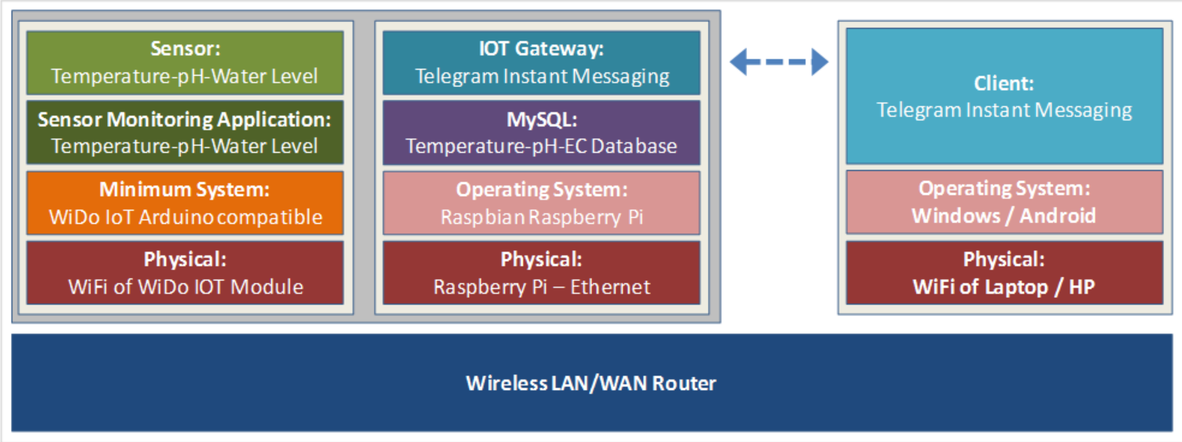

FIGURE 2. Hydroponic IoT software system architecture

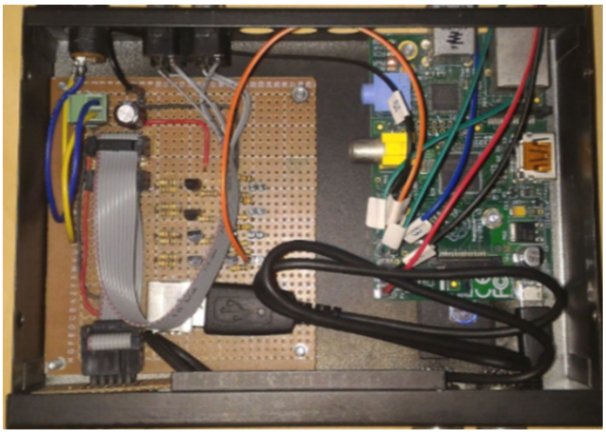

FIGURE 3. Raspberry Pi module

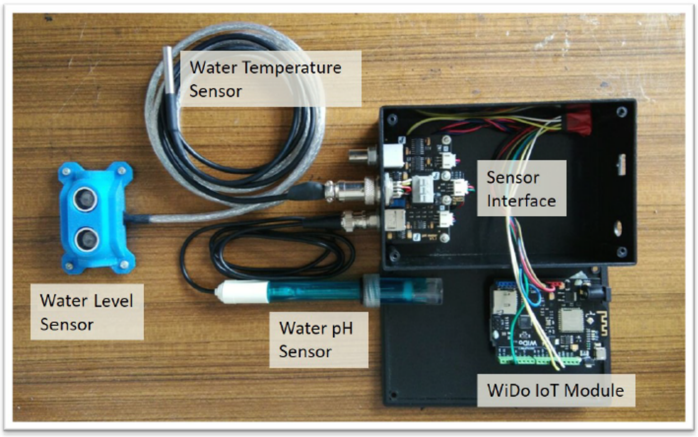

FIGURE 4. Sensors on the WiDo IoT module

As shown in Figure 4, there are three sensors connected to the WiDo IoT module through each interface. The temperature sensor is connected to one of the digital pins while the pH sensor is connected to one of the analog pins. The proximity sensor requires 2 digital pins from WiDo. The wireless Ethernet module is available on the WiDo IoT module, so measurement results from a session can be sent to Raspberry Pi via the wireless LAN network.

3.4. **Software implementation.** As in the hydroponic IoT software system architecture design drawings, there are three main applications running on the Raspberry Pi, namely: MySQL database server, APACHE Web server and telegram instant messaging. The process of writing data to the MySQL database uses a PHP script that will run when the IoT module sends data to the Raspberry Pi. For remote monitoring a BOT application needs to be added which functions to read data from the database and forward it to the telegram BOT instant messaging according to the request requested by the client.

Adafruit_CC3000 library is used for wireless LAN communication programming and OneWire library for temperature sensor programming on the WiDo IoT module. Whereas for debugging purposes the SPI library is used for serial communication. Other application modules that are embedded in WiDo are water level measurements, and pH measurements.

3.5. **Testing result.** This section will provide a report of testing software and hardware development on a hydroponic system that serves as a real model of implementing smart monitoring using IoT.

3.5.1. *WiDo IoT module.* The WiDo IoT module transmits data from the pH, temperature and water level sensors using the Wi-Fi module. WiDo IoT is conducting a network initiation and requesting an IP Address using DHCP.

After getting an IP Address, the connectivity test can be done by performing a PING command to the IP Address of the WiDo IoT module from the terminal. This indicates that WiDo IoT has been connected to the Intranet network properly.

WiDo IoT module will take measurements using the sensor it has and will send the measurement results to the MySQL database server in Raspberry Pi. Figure 5 shows an example of the output monitoring of the serial port in the WiDo IoT module.

```
pHvalue:8.24   Temp:29.31^C   WaterLevel:14Cm
pHvalue:8.24   Temp:29.31^C   WaterLevel:15Cm
pHvalue:8.24   Temp:29.31^C   WaterLevel:15Cm
pHvalue:8.24   Temp:29.31^C   WaterLevel:14Cm
pHvalue:8.24   Temp:29.31^C   WaterLevel:15Cm

Preparing to send HTTP GET Request ...
Connecting to WEB Server
--> Connected

Sending request:
GET /WriteData.php?pH=8.24&Tp=29.31&WL=14.00 HTTP/1.0

Reading response
-------------------------------------
HTTP/1.1 200 OK
Date: Sun, 07 Jan 2018 11:27:25 GMT
Server: Apache/2.2.22 (Debian)
X-Powered-By: PHP/5.4.45-0+deb7u5
Vary: Accept-Encoding
Content-Length: 23
Connection: close
Content-Type: text/html

New record created successfully
-------------------------------------

Closing Socket
```

FIGURE 5. WiDo serial monitoring output

The measurement results are sent using an HTTP GET request to the APACHE WEB server on the Raspberry Pi. From the output above there are 2 measurements that have been successfully saved to the database.

3.5.2. *Raspberry Pi module.* In this study use the MySQL application as a database server that is installed in the Raspberry Pi. The results of sending data from the WiDo IoT sensor module are stored in the 'sensor' table of the "Hydroponic" database (Figure 6).

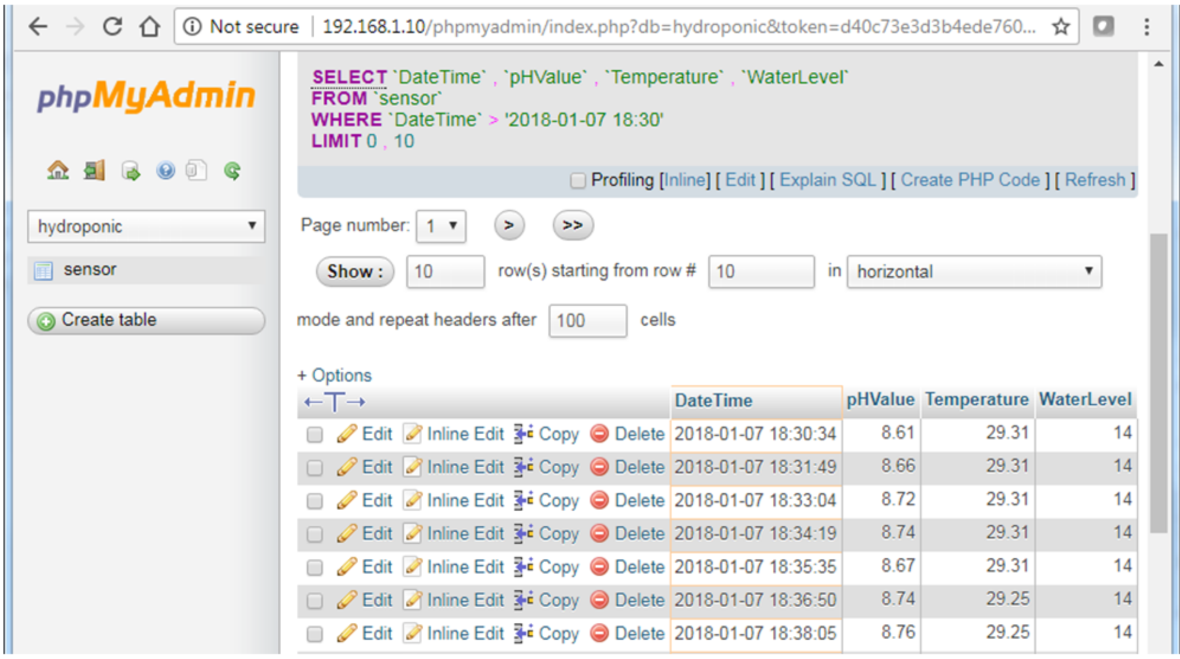

FIGURE 6. MySQL database

As an IoT Gateway, Raspberry Pi is equipped with the Bot Telegram application. Figure 7 shows the output of the client communication channel to see the status of the hydroponic system by sending a request from the menu in the telegram instant messaging application.

3.5.3. *Telegram instant messaging.* Telegram instant messaging is a channel of communication channel provided in this system so that clients can monitor several parameters of the hydroponic plant. To facilitate the use of monitoring, it is necessary to make several menus as shown in Figure 8.

Every successful command received by Raspberry Pi will get a reply in accordance with the requested data. There are 4 commands provided in smart monitoring to see the state of hydroponic plants, as follows:

- /status: see the overall measurement results for pH, temperature and water level
- /pH: see the results of the measurement of the water pH
- /temperature: see the measurement results for water temperature
- /water level: see the result of the measurement of water level

As shown in Figure 9, there are 4 examples of replies given by the system to the client in accordance with requests sent via telegram instant messenger. The measurement process is carried out every 10 seconds, so it allows different results within the same minute.

Figure 10 shows one example of a case to show water leakage in a hydroponic system tank. As a baseline, on 9 January the water level is 17cm. On the following day it was found that the height of the water became 15cm. Then the next day it was found that the water level dropped again to 13cm. The conclusion was that a water leak occurred with a decrease in water level of 2cm per day.

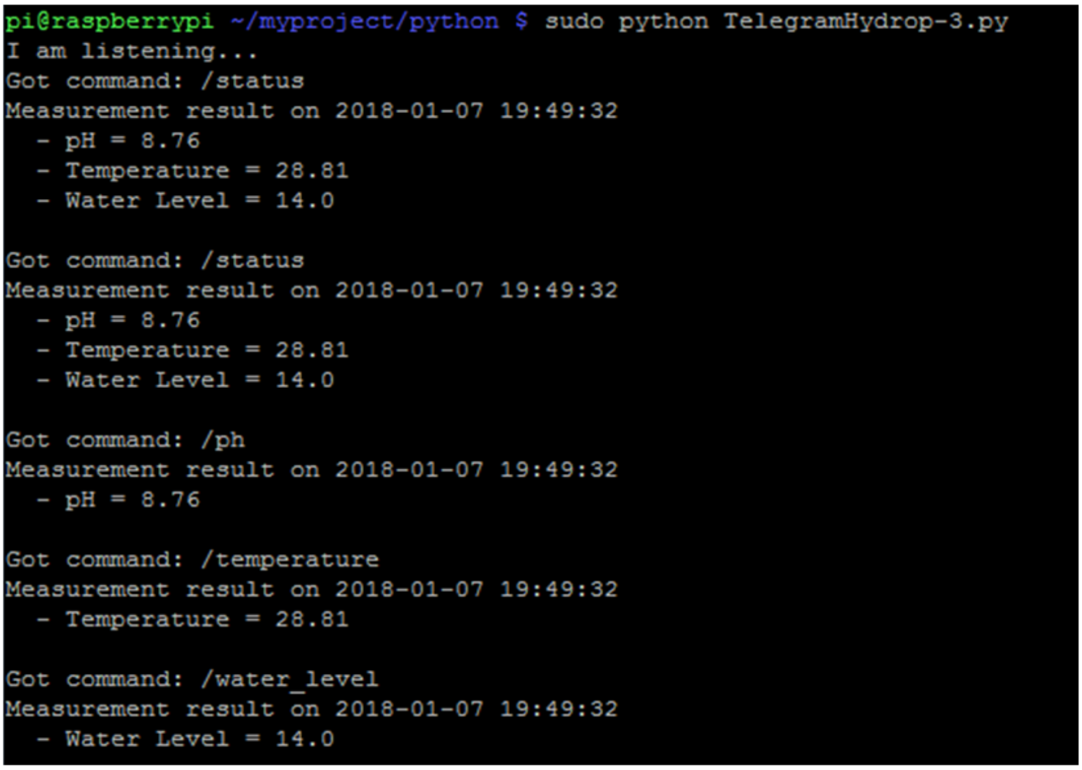

FIGURE 7. Telegram messenger monitoring

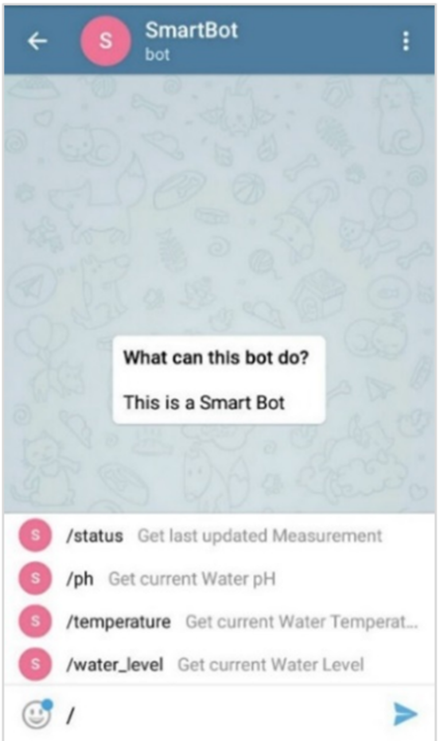

FIGURE 8. Menu

4. **Conclusion.** The conclusions obtained from the results of the development of smart monitoring on hydroponic systems using Raspberry Pi are as follows.

1) Raspberry Pi can work well as a database server and IoT Gateway by using telegram instant messaging as a communication channel.

Figure 9. Measurement results

Figure 10. Water leak detection

2) Placement of WiDo as an outdoor IoT module can work in hot or rainy conditions, but it must be ensured that the level of reception of Wi-Fi signal strength is strong enough so that data from measurements through sensors can be sent to the Raspberry Pi (Database Server) properly.

3) Telegram instant messaging can work stable on Raspberry Pi as IoT Gateway.

The next step of this research is to build a smart hydroponic system, not only monitoring but the system can act based on the monitoring result.

REFERENCES

[1] K. Rose, S. Eldridge and L. Chapin, *The Internet of Things (IoT): An Overview*, The Internet Society (ISOC), Reston, Virginia, 2015.

[2] M. Chui, M. Löffler and R. Roberts, The Internet of Things, *McKinsey Quarterly*, p.5, 2010.

[3] R. Jain, *Introduction to Internet of Things*, Documents from Washington University, Saint Louis, 2013.

[4] E. M. F. Jesus Jr. and M. C. M. Neto, LibsensorPy: A library to improve the development of ubiquitous applications on Raspberry Pi, *Proc. of the 21st Brazilian Symposium on Multimedia and the Web (WebMedia'15)*, Manaus, Brazil, 2015.

[5] A. McEwen and H. Cassimally, *Designing the Internet of Things*, Wiley, Chichester, 2014.

[6] Gartner Inc., *Gartner's Hype Cycle Special Report*, http://www.gartner.com/technology/research/hype-cycles/, 2011.

[7] J. Buckley, *From RFID to the Internet of Things – Pervasive Networked Systems*, Auerbach Publications, New York, 2006.

[8] The Raspberry Pi Foundation, *Get Started with Raspberry Pi*, www.raspberrypi.org/help/, Accessed on 20 May 2016.

[9] D. Briere and P. Hurley, *Wireless Home Networking for Dummies*, 4th Edition, John Wiley & Sons, 2010.

[10] M. Richardson and S. Wallace, *Getting Started with Raspberry Pi*, O'Reilly Media, Inc., Sebastopol, 2012.

[11] W. W. Gay, *Experimenting with Raspberry Pi*, Apress, 2014.

[12] Arduino Project Hub., *Arduino – Getting Started*, https://www.arduino.cc/en/Guide/HomePage, Accessed on 18 April 2016.

[13] R. Wiki, *DFRobot Product*, https://www.dfrobot.com/wiki/index.php/Main_Page, Accessed on 26 October 2016.

[14] F. U. Khan, Energy harvesting from the stray electromagnetic field around the electrical power cable for smart grid applications, *The Scientific World Journal*, vol.16, p.20, 2016.

[15] V. Zhmud, N. Kondratiev, K. Kuznetsov, V. Trubin and L. Dimitrov, Application of ultrasonic sensor for measuring distances in robotics, *Journal of Physics: Conference Series*, vol.1015, p.032189, 2018.

[16] fao.org, *Report of the World Food Summit*, Food and Agriculture Organization, Rome, 1996.