INVITED PAPER Special Section on Internet Technologies to Accelerate Smart Society

Smart Farm: Applying the Use of NodeMCU, IOT, NETPIE and LINE API for a Lingzhi Mushroom Farm in Thailand

Ekkarat BOONCHIENG[†a)], **Oran CHIEOCHAN**[††], *and* **Anukit SAOKAEW**[††], ***Nonmembers***

SUMMARY This research aims to find the best practice of prototyping a smart Lingzhi mushroom farm in Thailand. This research applied the use of NodeMCU with a humidity sensor and IOT platform to measure and monitor the humidity in the Lingzhi mushroom farm. The humidity data proceeds through NETPIE was developed and provided by NECTEC, Thailand as a free service for IOT. The humidity data was stored into a NET FEED (a sub service from NETPIE) and displayed on mobile devices and computers through NET FREEBOARD (another sub service of NETPIE). This technology also automatically controlled the sprinkler, fog pumps, and the functional status (switching on and off periodically) of push notifications through LINE API on the LINE Application. The equipment and tools used in this research were NodeMCU, humidity sensor, RTC (real time clock), relay module, sprinkler and fog pumps. C++ and Node.JS were used for programming. The services and protocol used were NETPIE (Network Platform for internet of everything) with subservices such as NETPIE FEED, NETPIE FREEBOARD, and NETPIE REST API. The LINE API was also included. The results of the research show that using NodeMCU with the humidity sensor and IOT platform demonstrates the best practice of smart farming.
key words: *NodeMCU, IOT, NETPIE, LINE API*

1. Introduction

The Thai government would like to promote Thailand 4.0 by using a new technology for Thai agriculture. Maejo University Chiangmai (agricultural university) has a concept to develop a prototype of smart Lingzhi mushroom farm by using current information technology to control the environment in Lingzhi mushroom farm. The reason for developing a smart Lingzhi mushroom farm is to promote a new modern agriculture to Thai farmers. The Lingzhi mushroom is considered as a new industrial crop for Thai farmers. Normally, to control the environment for mushrooms, light, temperature, humidity, and air flow need attention. [1] Research done by Maejo University showed that humidity was the most important factor for the growth of the spores of the Lingzhi mushroom leaves. This research used NodeMCU with a humidity sensor and IOT to measure and monitor the humidity in the Lingzhi mushroom farm as well as the control of irrigation.

Manuscript received March 28, 2017.
Manuscript revised May 25, 2017.
Manuscript publicized July 5, 2017.
[†]The author is with the Center of Excellence in Community Health Informatics, Department of Computer Science, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand.
[††]The authors are with School of Information Technology, Faculty of Science, Lampang Rajabhat University, Lampang, 52100, Thailand.
a) E-mail: ekkarat@ieee.org
DOI: 10.1587/transcom.2017ITI0002

2. Literature Review

IOT: Internet of Thing is an internet application which involves 3 kinds of technologies, that includes 1) perception, 2) transmission and 3) intelligent processing [2]. Internet of Things combines sensor technology, communication network, internet technology and intelligent computing technology to achieve reliable intelligent processing [3]. The protocol commonly used for the internet of things is MQTT. MQTT (Message Queuing Telemetry Transport) is a broken-based publishing/subscribing, instant messaging protocol. It's designed to be open, simple, lightweight and easy to implement. The advantage of MQTT protocol is that it solves the problem of instantly pushing various messages from the server to the mobile devices.

NETPIE: Network Platform for Internet of Everything is a Cloud-based platform as a service that facilitates interconnecting IOT devices (things) together in the most seamless and transparent manner possible by pushing the complexity of connecting IOT devices from the hands of application developers or device manufacturers to the Cloud. NETPIE also provides micro-gear libraries, firmware, and SDKs that facilitate communication channels and other functionalities between things and the NETPIE platform. Micro-gear is open-source. NETPIE is not managed by MQTT brokers. NETPIE creates our own publish-subscribe communication model that allows instant messaging among IOT devices (things). This communication model can support both the MQTT protocol and the HTTP REST protocol. To make things talk over the MQTT protocol, it uses the KEY and SECRET which we (these researchers) have created on the NETPIE web for authentication [4]. NETPIE is created and supported by the Thai government: NECTEC (Thailand: National Electronics and Computer Technology). It is a free Cloud-based platform service.

Figure 1 demonstrates the connection between IOT devices (NodeMCU) and NETPIE and the connection between user and NETPIE. NETPIE is considered as a middleware (Broker) and cloud service. An IOT device in this research is NodeMCU-12E with humidity sensor (DHT22/AM2302). Microgear is a library provided by NETPIE (NETPIE Chat.ino) and communication rate is 115,200 bits per second. User can connect to NETPIE via web browser.

The NETPIE services used in this research were microgear libraries, NETPIE FREEBOARD, NETPIE FEED and NETPIE REST API.

Fig. 1 The connection between IOT devices, NETPIE, and users.

NETPIE FREEBOARD is a subservice provided by NETPIE. It is similar to a free Dashboard which shows information on the web browser. Data can be visualized or monitored on real-time. NETPIE and NodeMCU-12E are connected and communicated using MQTT protocol with microgear library. To connect between NETPIE FREEBOARD (freeboard.io) and NETPIE a REST API Protocol (Representational State Transfer Application Programming Interface) is used. JSON format is also applied for data source.

NETPIE FEED is another sub-service provided by NETPIE. It is used as a database to keep data retrieved from the IOT system with sensors. Data can be retrieved from NETPIE FEED as a time-series.

NETPIE REST API (Representational State Transfer Application Programming Interface) is another sub-service provided by NETPIE and it can be called REST Web API. It is used to communicate, exchange and retrieve information as a web service by using an HTTP method such as get, put, post, delete and is formatted as JSON (JavaScript Object Notation).

LINE API provides a service named LINE Notify that can send messages or notices to the LINE Application. The service used is a common HTTP POST. The access token is applied as a code when using the LINE API [5].

In this research NodeMCU sends messages about the functional status by switching on and off from sprinkler and fog pumps to the API service. Notifications are then sent to the LINE Application.

NodeMCU is an open source IOT platform. It includes firmware which runs on the ESP8266 WI-FI SoC (System-on-chip) from Espressif Systems Company (from Shanghai, China). It is a 32 bit Microcontroller. In this research NodeMCU used ESP-12 module or NodeMCU version 2. NodeMCU is similar to the Arduino which has built in input and output ports. NodeMCU is compatible with Arduino IDE in the fact that programming C++ can be written for it. Compiling and flashing programming codes can be done using microB-USB. NodeMCU is more convenient than Arduino because it is smaller and can connect to WIFI [6].

2.1 Previous Research

The previous research [7] applied using IOT with RFID to find the best practice of logistic management for the Electricity Generation Authority of Thailand (EGAT) Mae Mao Mining, Lampang. The research applied the use of RFID for lignite coal trucks and data from RFID proceed automatically through a server and was stored into a private cloud computing. The equipment and tools used in their research was an RFID reader, UHF passive RFID tags, Arduino Mega 2560 + Ethernet Shield, PHP, Jason, Node.JS and Maria DB as a database system. The protocol used was MQTT. The results of the research showed that officers who worked for related systems were satisfied. The system enhanced the best practice of lignite coal mining logistic in terms of information checking.

In this research, the authors would apply the knowledge from the previous research mentioned above using IOT technology. NETPIE services developed by NECTEC, were also applied to process data via the internet. They were stored in a Cloud Computer and displayed on computers and mobile devices. In addition, the LINE API was also included as a functional status with notifications on the LINE Application. For the hardware selection, NodeMCU was selected instead of using Arduino Mega 2560 + Ethernet Shield suggested by the previous research.

3. Research Methodology

Following the waterfall model of the system development life cycle (SDLC), there are 5 steps in this research. Requirement and Feasibility study, system analysis and design, implementation, system validation, and maintenance.

3.1 Requirement and Feasibility Study

The requirement of this research was to create a prototype of a smart Lingzhi mushroom farm. The Lingzhi mushroom farm needed to be environmentally controlled specifically for humidity. The switching on and off of the water sprinkler and fog pump were required. Period of times of watering was dependent on the humidity of the Lingzhi mushroom farm. The suitable humidity needed by the Lingzhi mushroom farm should be 90–95%. Moreover, the system should be cost effective and require simple maintenance. Humidity data was sent to Cloud Computing (using NETPIE services) and was shown on computers and mobile devices. The status of watering was noted on computers and mobile devices.

For this research, we selected NodeMCU, IOT as smart technology for the smart Lingzhi mushroom farming. The tools, software and protocol used are shown in Fig. 1 and Tables 1–3.

3.2 System Analysis and Design

The research was done during the winter season. The average daily temperature was 20 to 25 degree Celsius. It was considered suitable for the growth of Lingzhi mushroom [8] Therefore, this research and the development of the IOT system was not designed to control and measure the temperature. However, a DTH22 is a bi-functional sensor measuring temperature and humidity at the same time. In this research, only the humidity of the Lingzhi mushroom

Table 1 Hardware and purpose of the use.

Hardware	purpose of the use
NodeMCU V2 (ESP8266 -12E)	Control devices and send data into the Internet via WIFI connection
Sensor DHT22 / AM2302	Temperature and humidity sensor
RTC I2C Module DS1307 (Real time clock)	Time stamp
Relay Module 2 channel 5 V	Control (switch on and off) sprinkler pump and fog pump
Sprinkler pump AC 220V 370W Q.Max 1.5m/h	Sprinkler irrigation
Fog pump 3.0 Lpm 12 BAR 24 VDC 2.5A	Fog irrigation
LCD 20X4 with I2C interface	Display functional status

Table 2 Software and purpose of the use.

Software	purpose of the use
C++ on Arduino IDE	Programming language on Node MCU
Node.JS	Information retrieval into JSON formatted on NETPIE REST API and information conversion into CSV formatted
WIFI Analyzer	To verify the WIFI signal strength
Andromo	Creating Android apps

Table 3 Service and protocol and proposes of the use.

Service and Protocol	purpose of the use
NETPIE (Network Platform for Internet of Everything	Platform and service of IOT for humidity data management
NETPIE FEED	Store humidity and time data on cloud computing
NETPIE FREEBOARD	Display humidity and time data on
	mobile devices
Line API (Application Programming Interface)	Notify functional status of sprinkler pump and fog pump on LINE Application
NETPIE REST API (Representational State Transfer Application Programming)	Information retrieval interface

farm needed to be measured. Functional status of sprinkler and fog pumps were needed to notify (switching on and off automatically). The average humidity should be 90–95%. The Lingzhi mushroom farm was designed using local materials. Light, air flow and air ventilation were not considered in this research.

3.2.1 Concept Diagram

In this research IOT was applied for use with a humidity sensor to measure the humidity of the Lingzhi mushroom farm and to control the switching on and off of water sprinkler and fog pump automatically. NodeMCU was applied as the hardware with WIFI for IOT connecting with Maejo University access Point to connect the internet. A service used to send humidity data to the internet was NETPIE, and a sub service used was NETPIE FREEBOARD to real-time display humidity data and time stamp on smartphones and computers [9]. Another sub NETPIE used was NETPIE FEED to record humidity data and time stamp on cloud services [10]. The information retrieval used was Node.JS

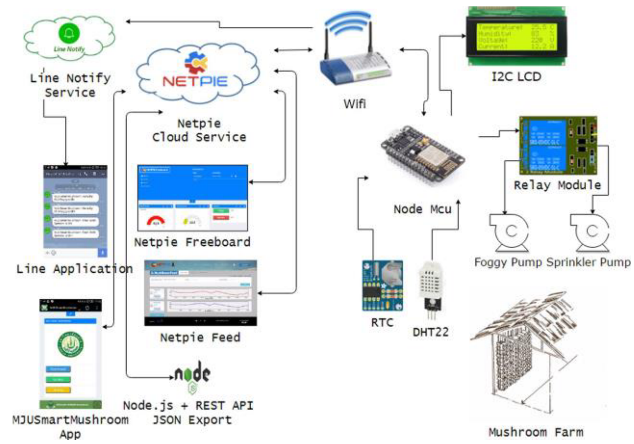

Fig. 2 A conceptual diagram of the integrated systems of smart Lingzhi mushroom farm monitoring and controlling using IOT, NETPIE and LINE API.

on NETPIE REST API [11].

For the monitoring of information of humidity, farmers could use NETPIE FREFORD and NETPIE FEED via HTTPS://netpie.io/. In the additional option, MJUSmartMushroom was used as mobile application running on Android to access NETPIE FREFORD and NETPIE FEED. LINE Notify was used to notice the functional status of water sprinkler and fog.

It should be noted, if there was no internet connection, NodeMCU with the DTH22 sensor still can measure humidity of the Lingzhi mushroom farm. The control of irrigation was still automatically functioning, as well as the switching on and off of the sprinkler and fog pumps. However, only the humidity data was not processed into NETPIE, the humidity data was not shown on mobile devices, and the humidity data was not stored into cloud computing.

3.2.2 Hardware Connection Diagram

In this research, NodeMCU V2 (ESP8266 -12E) was applied as an IOT platform. It was used to connect and control devices and send humidity data to the internet via WIFI connection. DS1307 was used as a real time clock for time stamp. DHT 22 was used as humidity sensor. Two relay modules were used to control irrigation systems (sprinkler and fog pumps). LCM 1602 IIC was used as convertor to connect between an LCD screen and NodeMCU. The overall wiring diagram is shown on Fig. 3.

3.2.3 Flow Chart Diagram

The total time to cultivate Lingzhi mushroom is between 90 and 120 days. The first 40 days are in the nursery farm. From day 40 to 120 they are cultivated in the Lingzhi mushroom farm for the purpose of spore and leaf collection. A water irrigation sprinkler is used in the first 20 days and is needed for the Lingzhi mushroom leaves, to accelerate the process of increasing mushroom spores. The irrigation of the water

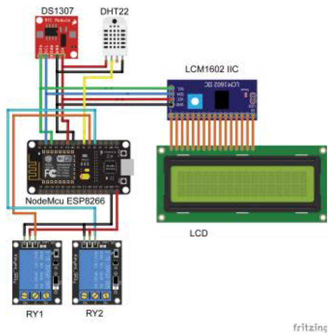

Fig. 3 Wiring diagram of intergraded systems of smart Lingzhi mushroom farm monitoring and controlling using NodeMCU.

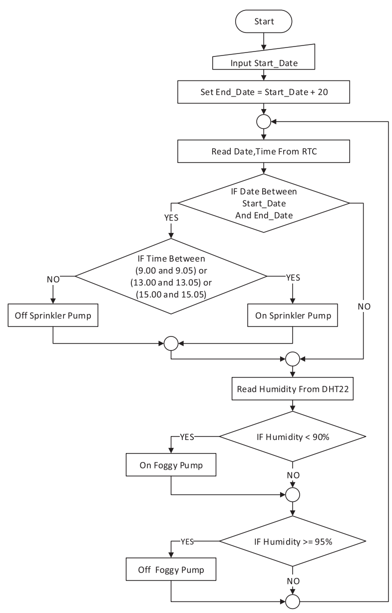

Fig. 4 The flow chart of condition of watering Lingzhi mushroom farm on sprinkler and fog systems.

sprinkler happens 4 times a day (09:00, 11:00, 13:00 and 15:00 o'clock) and lasts 5 minutes each time. The moisture needs to be controlled and is needed throughout the period of the Lingzhi mushroom cultivation. The humidity must be between 90–95 percent.

3.3 Implementation

Before the implementation, NodeMCU and humidity sensor were tested for sensitivity at 3 locations of the Lingzhi mushroom farm, in front of the farm, in the middle of the farm and at the end of the farm. The results show that there was no difference in humidity values for the 3 locations. Then Electronic devices were put together in a waterproof control box. The installation of the control box is located at the front of the mushroom farm. Sprinkler and fog pumps were allocated at the back of the Lingzhi mushroom farm. There were 3,500 Lingzhi mushroom cultivated in the mushroom farm. The size of the mushroom farm was 4 X 6 X 3 meters

Fig. 5 Sprinkler and fog pumps were allocated at the back of the Lingzhi mushroom farm.

Fig. 6 Sprinkler and fog systems.

(width, length, height). Sensor DHT22 / AM2302 Temperature and humidity sensors were located in the middle of the mushroom farm.

In this research, two watering systems to control the humidity of Lingzhi mushroom farm were applied. The black tube was a sprinkler that was on the top. The white tube was a fog system below. The sprinkler system accelerated the process of increasing the Lingzhi mushroom spores. Water droplets were needed to cover the Lingzhi mushroom leaves. The fog system was used to control the humidity of the Lingzhi mushroom farm between 90-95 percent of humidity which was suitable for the growth of Lingzhi mushroom.

In order to connect to WIFI, nodeMCU supported WIFI standard IEEE 802.11b/g/n. In this research, Fixed IP address mode was taken to connect with Maejo University's WIFI. Free software named WIFI Analyzer [12] on mobile phone were used to verify the strength of the WIFI signal. The result of the WIFI signal was around −50 to −60 dBm which meant the signal was good. If IOT system (nodeMCU) connected to WIFI, the status of the connection was shown on the screen.

3.4 System Validation and Maintenance

In order to make sure the humidity sensor and IOT system cloud measured the humidity of the Lingzhi mushroom farm correctly, wet bulb and dry bulb thermometer was used for the validation.

The comparison of the results of humidity read by IOT and the wet and dry bulb thermometer (manual read) were taken into account. The humidity data in Fig. 8 shows that the humidity data read by the IOT system and the researcher went the same direction. However, the humidity data read by IOT was more detailed because the digits were in decimals.

Fig. 7 NodeMCU connecting WIFI.

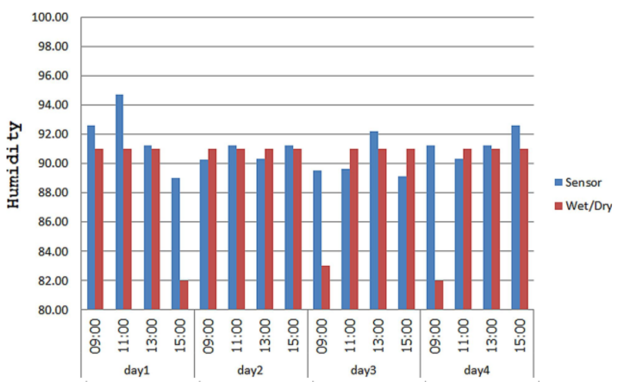

Fig. 8 A comparison between humidity data measured by IOT system and human (manual).

Fig. 9 IOT system and the wet and dry bulb thermometer measuring and monitoring the humidity of the Lingzhi mushroom farm.

For example, if the dry temperature was 22 Celsius and the wet temperature was 21, the humidity could be 91%. If the dry temperature was 22 Celsius and the wet temperature was 20, the humidity cloud be 82%.

A CCTV (closed-circuit television) was installed to monitor the status of the watering system switching on and off. It compared the data from the time stamp shown on NETPIE FREEBOARD and the LINE Application (Fig. 6).

4. Results

The humidity data read from the DHT22 sensor could be displayed in many ways. It can be shown on LCD where it's located in front of the control box. It could also be shown on mobile devices. NETPIE services with sub services such as NETPIE FREEBOARD and NETPIE FEED were implemented in this stage. The functional status of the sprinkler and fog pumps (switching on and off) and time stamp can be noticed via LINE Application. In addition, the mobile application, MJUSmart Mushroom was included.

Fig. 10 Humidity, temperature and time stamps were shown on LEC screen.

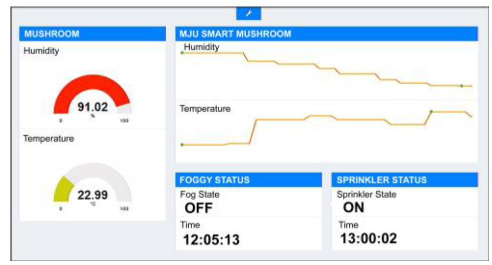

Fig. 11 Real time humidity data of the Lingzhi mushroom farm was shown on NETPIE FREEBOARD.

In Fig. 10, the humidity data was shown by an LCD timestamp. In case the internet was not working, the humidity data was not processed into NETPIE. However, the humidity data was still shown on the LCD screen. And the irrigation controlling system was still working (switching on and off sprinkler and fog pumps). Only the functional status of the irrigation controlling system was not sent to LINE Notifications.

NETPIE FREEBOARD (IOT Dashboard) is a web application provided by NECTEC. MJU smart Lingzhi mushroom farm was a private freeboard then Key and Secret were also needed and there were generated by NETPIE. It was an open-source, with real time updates and it was considered stable and reliable. It was supported by Google chrome, Firefox, Safari but did not include Internet Explore. In this research, a service of NETPIE FREEBOARD can display humidity data read from DHT22 every 5 minutes. Information consists of time stamps, status of sprinkler and fog pumps.

Humidity data read from DHT22 was stored into a cloud computing service of NETPIE FEED. Information could be displayed in a time series graph to monitor the change of humidity of the Lingzhi mushroom farm. Historical information of the humidity of Lingzhi mushroom farm also could be retrieved.

In was an optional function to use the LINE Application to notify the status of switching on and off Sprinkler and fog pumps and the time stamp. Members in a LINE group were informed. In this research, there were 5 members in the MUS Smart Mushroom LINE group.

Fig. 12 The graph of humidity data of the Lingzhi mushroom farm was shown on NETPIE FEED.

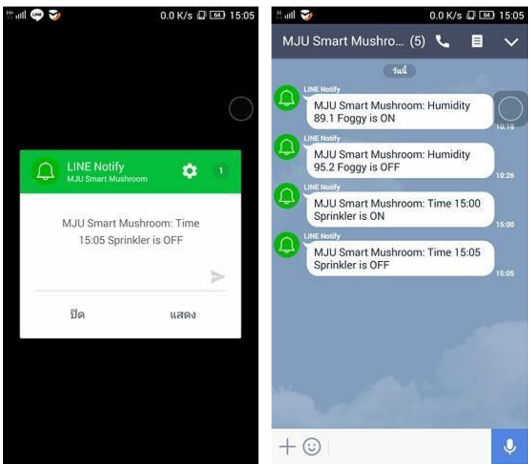

Fig. 13 Functional status of sprinkler and fog pumps were notified on LINE application.

Historical humidity data stored in service of NETPIE FEED could be retrieved by using REST API via method GET and the result would be in JSON format. Node.JS was applied as a program to retrieve humidity data into JSON format. The time was shown as GMT UNIX Timestamp (milliseconds). Due to the time differences, Thailand time, UTC + 7 was added. According to Fig. 14, the UNIX Stamp 1487390706069 was converted to a human readable date, 18 February 2017.

4.1 Mobile Application

In this research, mobile applications running on Android were created by the use of the Andromo application [13]. It is a free software that can create Android applications without coding. The purpose was to a make it easy for the farmers or the users (Lingzhi mushroom farm) to monitor the humidity data from the NETPIE FREEBOARD. As an access to NETPIE FREEBOARD, farmers needed to access the web browser as well as the (through HTTP protocol) AppID Key and Secret. The MJUSmartMushroom application was designed to reduce those processes to streamline the farmer's usage. The MJUSmartMushroom application also included function controls where the famer could stop the irrigation systems. In addition, the MJUSmartMushroom application provided setting functions that allowed users to change the number of times or period of times for the sprinkler.


```
{
    "feedid":"mushroomfeed",
    "description":"MJU Smart Mushroom",
    "since":[1,"months"],
    "granularity":[1,"hours"],
    "data":[
        {
            "attr":"Humidity",
            "unit":"%",
            "values":[
                [1487379005698,89.92500000000001],
                [1487379605844,89.79166666666669],
                [1487383206795,88.7030769230769],
                [1487386805660,85.85083333333334],
                [1487390405855,82.735]
            ]
        }
    ],
    "lastest_data":[
        {
            "attr":"Humidity",
            "values":[[1487390706069,82.2]]
        }
    ]
}
```


Fig. 14 JSON format retrieved from NETPIE feed.

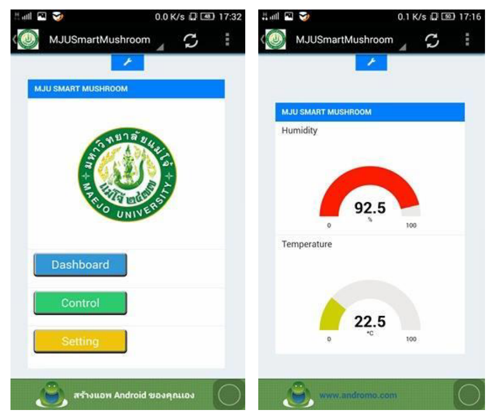

Fig. 15 MJUSmartMushroom application for mobile devices.

5. Discussion

There were 3 points discussed in this research. One was the economic perspective of the use of the IOT system being worth the investment. Second was the limitation of the use of the NETPIE FEED service from NETPIE. Third was the comparison between using IOT and the wet and dry bulb thermometer to measure the humidity of the Lingzhi mushroom farm.

First, the economic perspective, a newly developed IOT system was considered worth the investment. The electronic equipment cost approximately 2,000 Baths including NodeMCU V2 (ESP8266 −12E), Sensor DHT22/AM2302, Relay Module 2 channel 5 V, LCD 20X4 with I2C interface and some electric lines (excluding sprinkler and fog pump).

It assumes that the IOT is a computer. If one computer operated 20 hours a day for one month, the electricity bill would be 400 Baht [14]. The Lingzhi mushroom farm cultivated for 4 months. The electricity bill would be 400X4= 1,600 Baht. The labor cost, in Thailand, was 300 Baht per 8 hour working day. It would cost 9,000 Baht per month.

Table 4 The comparison the cost between using IOT and human to measure humidity and control irrigation management.

	Labor cost	Baht	IOT cost	Baht
	4 moths		Electronic devices	2,000
			Electricity 4 moths	1,600
		36,000		3,600

9000 x 4 months = 36,000 Baht to employ laborers to measure humidity, and switch the sprinklers and fog pumps on and off.

It would be approximately 10 times cheaper if you compared the use of the IOT systems and manpower for the same job. Moreover, IOT was planned to be used as an automatic system for approximately 3 to 5 years due to the deterioration of electronic devices and new technologies replacing IOT systems.

Second, NETPIE FEED is available free for users. IT is developed and provides services by NECTEC. IT needs to share resources appropriately. FEED rate is limited to writing the API key to four times in about 60 seconds or 15 seconds on average to be written in one spot. It should be noted that NETPIE FEED allows data to be stored for one year. Reading data from NETPIE FEED is limited to 5 times in 4 seconds.

Lastly, the advantage of using IOT to measure the humidity of Lingzhi mushroom farm was that the IOT could measure the humidity in decimal digits of precision. The wet and dry bulb thermometer was measured manually (read by human) and error could have occurred.

Additionally, the Mean Absolute Percentage Error (MAPE) was applied to measure the size of the error in percentage terms. It was calculated as the average of the unsigned percentage error [15]. In this research, the comparison between the percentage of humidity measured by the IOT system and read by humans on wet and dry bulbs thermometer was taken. The sampling of humidity data was taken over the course of four days and the times from 09:00, 11:00, 13:00 and 15:00 o'clock.

$$MAPE = \left[\frac{\sum |iot\ system - human\ measure| \div iot\ system}{n} \right] \times 100$$

The results compared the calculated error; the average difference between humidity data read by IOT system counts and human is 2.2%. It means that the RFID system is reliable, when $\alpha = .05$ (5% of error).

6. Conclusion

NodeMCU, IOT Technology was used to apply for the smart Lingzhi mushroom farm. The development of the IOT system has operated for 4 months through the Lingzhi mushroom cultivation period of times. The developed IOT system was considered stable. Humidity data was considered reliable and accurate (if compare to information done manually). The functional status of the sprinkler and fog pumps was done correctly. The project leaders of the smart Lingzhi mushroom farm from Maejo University, ChiangMai were satisfied.

Table 5 The MAPE (Mean Absolute Percent Error) between humidity data measured by IOT system and manual measuring.

Time	IOT	Human	Mean absolute percentage error (MAPE) α = .05
09:00	93.5	91	(|93.5-91|÷93.5)x100 = 2.67 %
11:00	95.2	91	(|95.2-91|÷95.2)x100 = 1.57%
13:00	91.3	91	(|91.3-91|÷91.3)x100 = 0.32 %
15:00	89.5	82	(|89.5-82|÷89.5)x100 = 8.21%
09:00	90.2	91	(|92.0-91|÷92.0)x100 = 1.08%
11:00	91.3	91	(|91.3-91|÷91.3)x100 = 0.32%
13:00	91.5	91	(|91.5-91|÷91.5)x100 = 0.54%
15:00	91.5	91	(|91.5-91|÷91.5)x100 = 0.54%
09:00	90.4	83	(|90.4-83|÷90.4)x100 = 8.18%
11:00	91.3	91	(|91.3-91|÷90.3)x100 = 0.33 %
13:00	92.4	91	(|92.4-91|÷92.4)x100 = 1.51%
15:00	89.2	91	(|89.2-91|÷89.2)x100 = -2.01 %
09:00	91.0	82	(|91.0-82|÷91.0)x100 = 9.89%
11:00	91.4	91	(|91.4-91|÷91.4)x100 = 0.43%
13:00	91.5	91	(|91.5-91|÷91.5)x100 = 0.54%
15:00	92.0	91	(|92.0-91|÷92.0)x100 = 1.08%
SUM = 35.2			
MAPE = 35.2/16 = 2.2 %			

7. Future Research

Future research could be done for the improvement of IOT system for the smart farm. Firstly, the data back up system such as a SD card should be included when there was no internet connection. Humidity data could not be processed into NETPIE, but the humidity data could still be recorded into an SD card for backing up.

Secondly, Solar cell should be applied to integrate into a current IOT system. A new developed IOT system should be portable and easy to use for farmers in the isolate area.

Thirdly, Linkit One with GSM should be applied to replace NoeMCU, in the case of the Lingzhi mushroom farm having no WIFI connection, GSM would be an option.

Finally Maejo University, compares the growth of the Lingzhi mushroom between the farm using an IOT system and traditional manual.

Acknowledgments

The authors are thankful to Mr. Supak Punya, Mr. Precha Ratanung and Mr. Somchai Araypitaya from Maejo University for the smart farm project. The authors would also like to express their gratitude to Maejo University who helped facilitate this research.

This work is supported by Thailand Research Fund under grant number RTA6080013.

References

[1] P. Ratanan, "Lingzhi Mushroom Farm," handout, Faculty of Agricultural Production, Maejo University, 2012 (Thai translation).
[2] L. Wei and Z. Gao, "Study on IOT based architecture of logistics service supply chain," International Journal of Grid and Distributed Computing, vol.7, no.1, pp.169–178, 2014.
[3] X. Xu, T. Chen, and M. Minami, "Intelligent fault prediction system based on internet of things," Comput. Math. Appl., vol.64, no.5, pp.833–839, 2012.
[4] NECTEC, "NETPIE: Internet of Things," https://www.nectec.or.th/innovation/innovation-software/netpie.html (access on 27/02/2017)
[5] LINE Developers, "Documents: Messaging API," https://developers.line.me/messaging-api/overview (access on 25/02/2017)
[6] GitHub, "NodeMCU," https://github.com/nodemcu (access on 25/02/2017)
[7] O. Chieochan, A. Saokew, and A. Boonchieng, "An in-tegrated system of applying the use of Internet of Things, RFID and Cloud Computing: A case study of logistic management of Electricity Generation Authority of Thailand (EGAT) Mae Mao Lignite Coal Mining, Lampang, Thailand," The 2017-9th International Conference on Know-ledge and Smart Technology, pp.156–161, 2017.
[8] P. Ratanan, "Lingzhi Mushroom Farm for Famers," handout, Faculty of Agricultural Production, Maejo University, 2014 (Thai translation).
[9] GitBook, "NETPIE FREEBOARD," https://github.com/netpieio/netpie-freeboard (access on 25/02/2017)
[10] GitBook, "NETPIE FEED," https://netpie.gitbooks.io/6-netpie-feed/content/5.html (access on 25/02/2017)
[11] GitBook, "NETPEE FEED: How to retrieve information from FEED" https://netpie.gitbooks.io/6-netpie-feed/content/4-feed.html (access on 25/02/2017)
[12] TechLogon, "Using WIFI analyzer to improve wireless performance," http://techlogon.com/2012/06/22/using-wifi-analyzer-to-improve-wireless-performance/ (Access on 12/03/2017)
[13] Andromo, "Create android apps without coding," http://www.andromo.com (access on 12/03/2017)
[14] ASTV Manager Online, "Green Innovation Energy savings," http://www.manager.co.th/iBizChannel/ViewNews.aspx?NewsID=9570000119308 (access on 25/02/2017)
[15] A. Davydenko, "How to Measure the Quality of Demand Forcasts Efficiently: A New Class of Forecasting Performance Metric," LUNS' Lnaugural Research Conference, Lancaste, UK, June 2010.

Ekkarat Boonchieng has completed a Ph.D. in Computer Science from the Illinois Institute of Technology, United States. He is currently working at the Department of Computer Science as Associate Professor, Faculty of Science Chiang Mai University. His research focuses on biomedical engineering and image processing and computer graphics.

Oran Chieochan has completed a Ph.D. in Information Systems Management from Charles Sturt University, Australia. He is widely experienced in industrial and business sectors in Thailand and overseas. He is currently a full time lecture in the school of Information Technology, Lampang Rajabhat University, Thailand. His research focuses on the use of Information Technology in developing countries.

Anukit Saokaew has completed a master's degree in Internet and Information Technology from Naresuan University, Thailand. He currently is a full time lecture in school of Information Technology, Lampang Rajabhat University, Thailand. He is also a consultant for Goodview Product Company, to import and installation of vehicle inspection equipment. His research focuses on embedded systems and applying to the use of information technology in agriculture.