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Control and Realtime Monitoring System for Mushroom Cultivation Fields based on WSN and IoT

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Control and Realtime Monitoring System for Mushroom Cultivation Fields based on WSN and IoT

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Abstract. In this article, it is explained the design of control and monitoring systems for many mushrooms cultivation fields (kumbung) in realtime based on Wireless Sensor Network (WSN) and the Internet of Things (IoT). This system is designed to control and monitor temperature and humidity parameters in each kumbung. The system consists of several node boards in each kumbung and master board. The main components of the node board consist of Arduino Uno which is connected to XBee, DHT22 sensor, actuator in the form of a sprayer-pump, a blower and lamp. The main components of the Master board are Raspberry Pi and Xbee. Data is sent from each node to the Master using the WSN network with data packages that contain temperature and humidity data with the ID of each kumbung. The master board sends all kumbung data through a WiFi network to the Firebase realtime database that can be monitored via a smartphone. Kumbung control is performed by an actuator at each board node. The actuator keeps the temperature betwen 26-29^{0}C and the humidity betwen 70-90%RH for mushrooms in the phase of body formation. The results of this system prototype experiment show that the functionality of the system is running well, although there is an average error 0,465^{0}C for temperature readings and an average error 2,67% for humidity readings. This error is still in the DHT22 working area based on the datasheet.

1. Introduction

Oyster Mushroom is one of the alternative food / protein ingredients for people's welfare and health [1]. Oyster mushrooms, especially white oysters, are a type of wood mushroom that have a higher nutrient content compared to other types of mushrooms. This mushroom contains protein, fat, phosphorus, iron, thiamin and riboflavin higher than other types of fungi [2]. Oyster mushrooms began to demand early in 2011 and become an alternative source of new protein for the people of Mesuji, Lampung. Currently the cultivation of oyster mushrooms is a prospect in Lampung, because demand as an alternative source of protein is increasing. Yepta, an oyster mushroom farmer, a resident of Sumberarum village, Kotabumi sub-district, Lampung, said that oyster mushroom cultivation can be used as an alternative business for families, She said that this cultivation is beneficial because raw materials are quite cheap and abundant [3].

In the cultivation of oyster mushrooms required Kumbung. Kumbung is a house made of wood or bamboo which is used as a place to treat baglog mushrooms and grow mold. While mushroom baglog is a growing medium as a place to put mushroom seeds. Kumbung must have the ability to maintain temperature and humidity, so that the mushrooms can grow optimally. Control of kumbung conditions is usually done manually, by spraying water on mushroom baglog 2-3 times a day, depending on the conditions. The mushroom requires a temperature of 26-29^{0}C with 70-90% humidity in the phase of the formation of the mushroom body [4].

With the increased demand for mushrooms, more farmers are making more kumbung, so that more operational costs in monitoring and controlling temperature and humidity per kumbung. Therefore, new innovations are needed that can help the community, especially farmers, in managing their kumbung.

In the industrial era 4.0, one of the supporting technologies is the Internet of Things (IoT). The reason is that IoT covers almost all aspects of human life, including industry, business, medical, agriculture, infrastructure, communication, household, and many other aspects of human life [5]. The concept of the Internet of Things allows communication / connectivity between all objects that surround human life, such as computers, smartphones, televisions, cars, motorcycles, and others, even kumbung/mushrooms. With this connectivity, we can control and or monitor the condition of kumbung anytime, anywhere, as long as there is internet and power supply.

IoT technology aims to build a set of networks where each object is connected [6]. When many kumbung are scattered and want to be monitored and controlled in a set of internet networks, Wireless Wireless Sensor (WSN) can be applied. WSN was recognized as the main driver of the Internet of Things (IoT) paradigm from the start. WSN is a data collection technology from each node that is distributed fairly tough and effective [7].

Environmental sensing is important because a large number of WSN applications have been developed for environmental sensing. Environmental sensor data collected such as humidity, temperature, and air quality and soil moisture can be analyzed for better decision making [8]. When multiple sensors monitor physical areas, WSN design is needed, because WSN is a technology where both sensors and networks work together to enable communication using wireless transceivers [9]. Wireless sensors have sensors that have processing, communication and storage capabilities [10].

This article discusses the design and prototype testing of WSN-IoT network infrastructure models for smart kumbung that can be applied in solving the problems of oyster mushroom farmers so that the benefits can streamline energy and operational costs in managing many kumbung. Farmers can monitor and control the many kumbung that are scattered wherever and whenever, via smartphone.

2. System Design

Research on smart kumbung with realtime temperature and humidity control and monitoring functionality has been carried out including [11] Hadi uses an ATmega 16 microcontroller with SHT11 sensor and a water cooler actuator and humidifier to control the temperature and humidity of the kumbung displayed on the LCD. It does not yet use the IoT platform where data is stored in the cloud so that it can't be accessed for specific purposes anywhere in real time. Then Fitriwaran, et al. [12] using Ubidots as an IoT platform. In controlling and monitoring temperature and humidity remotely with the Ubidots platform, they use Arduino MEGA 2560 with Ethernet shield W5100 as a WiFi module. Prototype that has been built this is still limited to just one kumbung. Sofwan et al. [13] is also still a prototype for one kumbung. They use the Blnyk web server as an IoT platform with an ATMega328 microcontroller plus an Esp8266 WiFi module. The sensor used by the DHT22 with the actuator is a blower, mist maker, sprayer-pump and thermo-electric cooler.

In research [14] Maulana et al. using WSN technology to monitor water quality in shrimp aquaculture in real time. They use Xbee for a wireless communication system between nodes in each shrimp aquaculture location with the master board. Data packets sent from each node that have a aquaculture ID are sent to the Raspberry Pi 2 master board. Then the master board with the help of a WiFi modem is sent and stored on a database server, so that it can be monitored through the website or smartphone application. The results obtained are an online monitoring system capable of monitoring water quality with parameters DO, pH, conductivity and temperature in each shrimp aquaculture

The architectural design of the WSN and IoT-based smart kumbung systems proposed to be able to control and monitor the temperature and humidity of many kumbung can be seen in Figure 1. This architectural design was inspired by the WSN architecture design for shrimp aquacultures in the Maulana study [14].
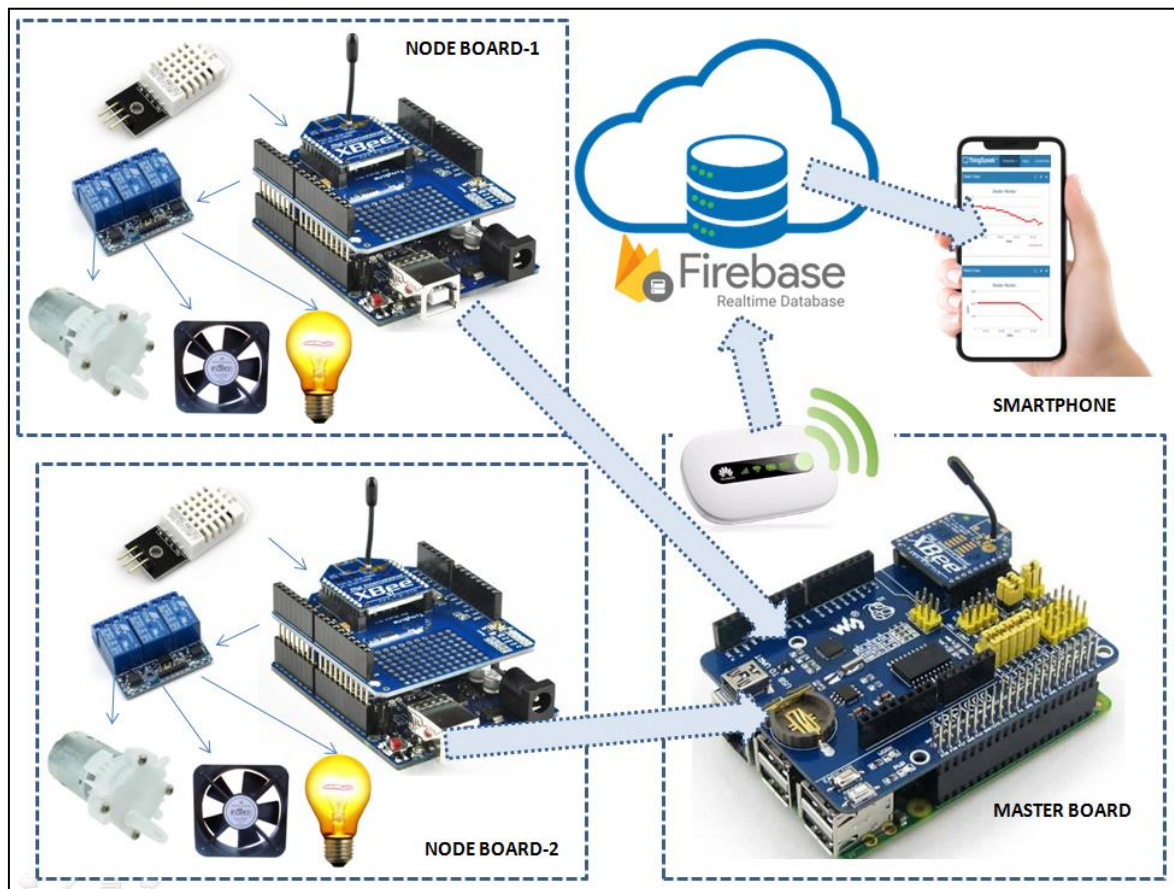
Figure 1. WSN-IoT-based smart kumbung architecture design

Digi Xbee System is one of the Wireless Sensor Network (WSN) platforms [15]. An Xbee network is commonly called a PAN (Personal Area Network). Xbee is a wireless data communication device that works at 2.4 GHz frequency with the standalone IEEE 8002.15.4 protocol. Xbee has been widely used for several applications including WSN for monitoring humidity, temperature, speed and wind.

DHT22 is a sensor used to sense temperature and humidity. This sensor has a fairly fast and accurate capability and a wide reading distance, reaching a radius of 20 m. This sensor works at 0-100% humidity range and temperature at $40\text{-}80^0$C range. The accuracy of the DHT22 sensor is 0.5^0C for temperature readings and $\pm$ 2% for humidity readings [16]. Kurniawan [17] uses DHT11 in monitoring temperature and humidity based on IoT, but DHT11 is still lacking a wide range of temperature and humidity readings. Whereas Nasution [18] uses SHT11 in monitoring IoT-based temperatures and humidity, but SHT11 is too broad in scope. To control the temperature and humidity of the muhsroom in the formation phase of the body, with temperatures betwen $26\text{-}29^0$C and humidity betwen70-90% RH, the DHT22 is more possible.

The actuators used to control temperature and humidity in the environment in the kumbung are using blowers and sprayers as well as incandescent lamps which are assisted by 3 relay channels. Blowers and sprayers are used to stabilize hot and dry temperatures, while incandescent lamps are used to stabilize temperatures that are too cold and too humid.

The need for major electronic components and their use for WSN-IoT-based smart kumbung can be seen in Table 1.

Table 1. The need for major electronic components

No	Major components	Qty	Usability
1	Raspberry Pi	1	As a master board
2	Modem WiFi	1	As an access point master board
3	Arduino Uno	2	As a node board microcontroller
4	Xbee	3	As a wireless communication system between nodes to the master board
5	Sensor DHT22	2	As a temperature and humidity sensor
6	Relay 3 channel	2	As a 220 AC voltage breaker
7	Lamp	2	As an actuator to heating
8	Sprayer-pump	2	As an actuator to cooling
9	Blower	2	As an actuator to cooling

Flowchart design of temperature and humidity control in each node of kumbung can be seen in Figure 2.
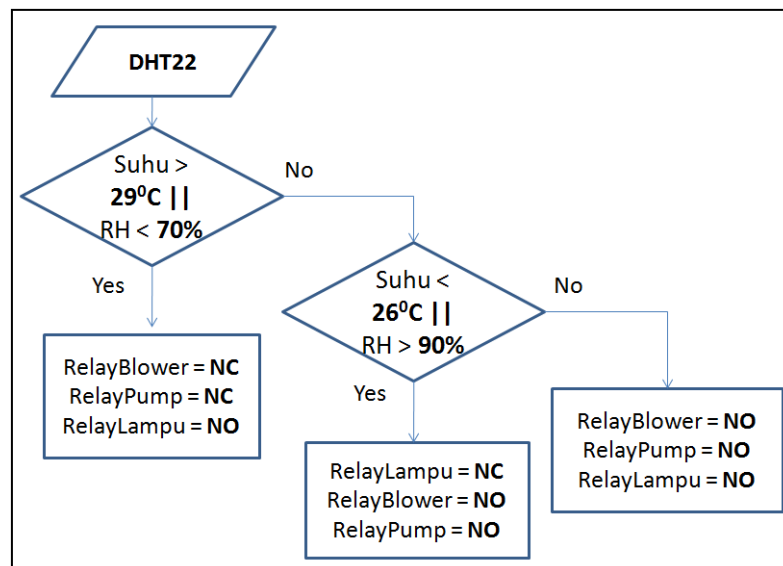
Figure 2. Flowchart how DHT22 works

The way DHT22 works in each kumbung is to maintain a temperature between 26-29^{0}C and humidity between 70-90% RH. When the temperature of the kumbung is hot or dry, the actuator will stabilize with the switch-on the sprayer and blower. When the temperature of the kumbung is cold or humid, the actuator will stabilize with switch-on the incandescent lamp.

3. Results and Discussion

3.1. Result
The WSN-IoT-based smart kumbung prototype can be seen in Figure 3. The test scenario is to look at the performance of the DHT22 sensor, actuator responses in maintaining temperature and humidity, and see the interface through a smartphone. These trials are in prototype environments and under normal conditions, the power supply and internet signal are strong.
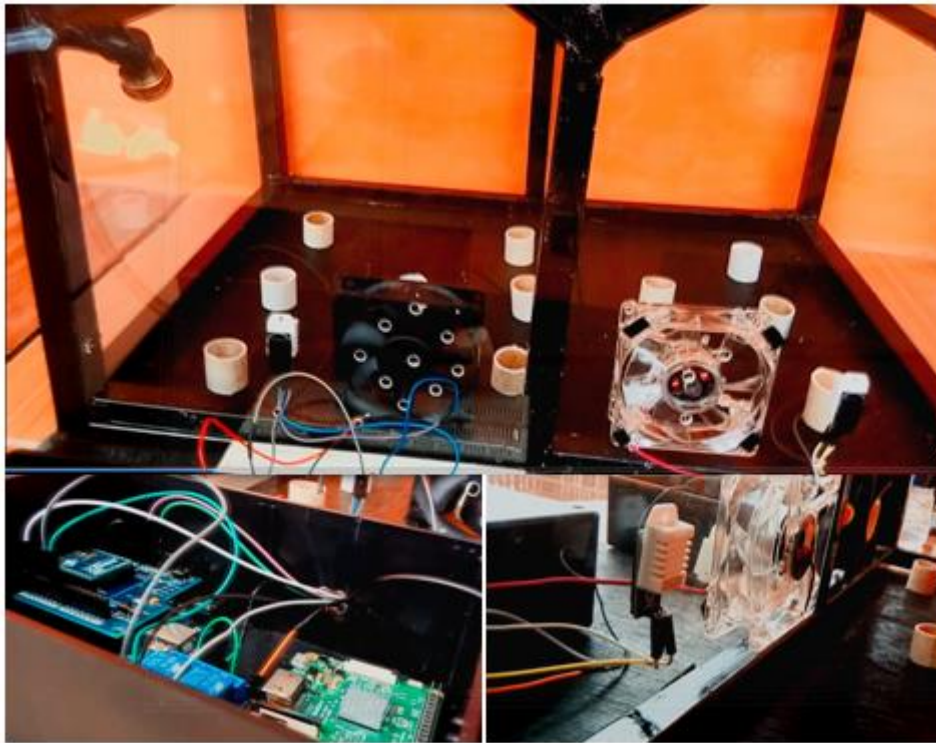
Figure 3. Smart kumbung prototype based on WSN-IoT

DHT22 sensor reading test results can be seen in Table 2 below.

Table 2. DHT22 sensor reading test results

No	Temperature (^{0}C)			Humidity (%RH)		
	Sensor	Instrument	Error	Sensor	Instrument	Error
	Kumbung Node-1					
1	27.75	28.24	0.49	92.56	95.38	2.82
2	28.9	29.36	0.46	90.24	92.98	2.74
3	26.85	27.26	0.41	94.97	97.89	2.92
4	27.95	28.42	0.47	92.92	95.84	2.92
5	28.05	28.48	0.43	88.89	92.31	3.42
6	29.2	29.65	0.45	70.35	73.82	3.47
7	29.15	29.63	0.48	60.98	64.44	3.46
8	29.45	29.86	0.41	61.70	65.15	3.45
	Eror rate temperature		**0.45**	Eror rate humadity		**3.15**
	Kumbung Node-2					
1	28.85	29.28	0.43	91.24	93.65	2.41
2	29.49	30.06	0.57	90.34	92.81	2.47
3	30.65	31.16	0.51	81.97	85.42	3.45
4	30.98	31.43	0.45	81.47	83.94	2.47
5	31.35	31.87	0.52	76.36	78.81	2.45
6	31.89	32.35	0.46	75.89	78.37	2.48
7	32.65	33.12	0.47	60.57	63.15	2.58
8	32.34	32.76	0.42	60.99	63.44	2.45
	Eror rate temperature		**0.48**	Eror rate humadity		**2.29**

The results of the actuator response test to the condition of the relay can be seen in Table 3 below.

Table 3. Actuator response test results to the relay condition

No	Relay			Aktuator		
	Ch-1	Ch-2	Ch-3	Blower	Sprayer	Lamp
Kumbung Node-1						
1	NC	NC	NO	ON	ON	OFF
2	NO	NO	NC	OFF	OFF	ON
3	NC	NC	NO	ON	ON	OFF
4	NO	NO	NC	OFF	OFF	ON
5	NC	NC	NO	ON	ON	OFF
Kumbung Node-2						
1	NO	NO	NC	OFF	OFF	ON
2	NC	NC	NO	ON	ON	OFF
3	NO	NO	NC	OFF	OFF	ON
4	NC	NC	NO	ON	ON	OFF
5	NO	NO	NC	OFF	OFF	OFF

The results of testing the system's functionality in controlling temperature and humidity can be seen in Table 4.

Table 4. WSN-IoT-based smart kumbung functionality test results

No	Sensor reading		Actuator		
	Temp. (^{0}C)	RH(%)	Blower	Sprayer	Lamp
Kumbung Node-1					
1	27,75	92,56	OFF	OFF	ON
2	28,9	90,24	OFF	OFF	ON
3	26,85	94,97	OFF	OFF	ON
4	27,95	92,92	OFF	OFF	ON
5	28,05	88,89	OFF	OFF	OFF
6	29,45	61,70	ON	ON	OFF
7	29,15	60,98	ON	ON	OFF
8	29,2	70,35	ON	ON	OFF
Kumbung Node-2					
1	32,34	60,99	ON	ON	OFF
2	32,65	60,57	ON	ON	OFF
3	31,89	75,89	ON	ON	OFF
4	31,35	76,36	ON	ON	OFF
5	30,98	81,47	ON	ON	OFF
6	30,65	81,97	ON	ON	OFF
7	29,49	90,34	ON	ON	ON
8	28,85	91,24	OFF	OFF	ON

The system interface can be accessed using an internet browser. The results of the system interface in monitoring the condition of both kumbung in realtime through a smartphone can be seen in Figure 4.

Figure 4. System interface via Smartphone

3.2. Discussion

From Table 2. The results of the DHT22 sensor readout test provide information that the mean error value is 0.465^0C for temperature readings and 2.67% for humidity readings. This error is still in the working area of the DHT22 component when referring to the datasheet. Based on datasheet the accuracy of this sensor is 0.5^0C for temperature readings and ± 2% for humidity readings (DHT22 Datasheet).

All actuators can work well and in accordance with the status of the relay conditions according to Table 3. In accordance with the flowchart where when the Relay-Normally Closed (NC) channel status then turn on the blower and the Normally Closed (NC) channel-2 then turn on the sprayer-pump while Relay channel 3 with NC status turns on incandescent lamp. And the opposite applies.

This smart kumbung system runs according to the work flowchart according to the test results of Table 4. Where the system maintains the kumbung condition so that the temperature is between 26-29^0C and humidity is between 70-90% RH. The system turns on the lamp to reduce humidity above 90% RH and will turn on the blower and sprayer to reduce the temperature when heat is above 29^0C.

4. Conclusion

The smart kumbung system based on WSN and IoT is functionally running well, where the actuator can automatically control the kumbung condition at a temperature of 26-29^0C and humidity of 70-90% RH. The mean error from sensor or system readings is 0.465^0C for temperature and 2.67% for humidity. This error is still in the working area of the DHT22 sensor based on the datasheet. The temperature and humidity of each kumbung can be monitored in realtime via a smartphone.

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