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# Monitoring and Controlling Temperature Egg Incubator Prototype Based LoRa Communication

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## ABSTRACT

Poultry industries encounter problem in produce day old chicken (DOC). Poultry industries usually produce DOC using egg incubator. Egg incubator must have high accuracy in reading environment temperature inside the machine. The temperature environment inside the egg incubator machine needs to keep in range 36°C - 40°C. On the other hand, hatcheries and chicken coop usually not in one place. Poultry industries require applied technology to solve this problem. This problem can be solved by using internet of things. But internet of things can be so expensive. This research is aim to implement monitoring and controlling temperature inside egg incubator prototype while using low-cost communication technology. Research result showed that the control system could maintain egg incubator prototype temperature in optimal range with an accuracy of 99,63%, 99,83%, 99,97%,99,64%, and 99,37% when reading a temperature of 36°C, 37°C, 38°C, 39°C, and 40°C respectively. This research implements Long Range (LoRa) technology for monitoring system. Different with internet of things technology, point to point LoRa communication does not needs payment to communicate but still provide wide area communication. According to research result, point to point LoRa communication provide good performance in sending temperature data in range area 50m, 100m, 150m, 200m, 250m, and 300m with good average Receive Signal Strength (RSSI). This research can conclude proposed egg incubator can keep temprature in optimal range. Proposed incubator also can communicate properly to send data temperature for monitoring temperature.

**Keywords***:* Egg Incubator, LoRa, Temperature, Daily Old Chicken

## INTRODUCTION

Industry 4.0 is characterized by development of various technology. The concept of industry 4.0 has begun to be implemented in the livestock industry, especially poultry farming [1]. Poultry farming has various obstacles in management especially for chicken farm. The application of technology is needed to improve of poultry farm [2].

In the post-COVID-19 pandemic, many industries are facing challenges. The poultry farming industry also has various challenges in many sctor such as in production process, supply chain, and environmental safety [3]. Poultry life cycle environment has always been a major challenge [4]. The chicken poultry farming industry focuses on two things, which is breeding and cultivation [5]. The breeding process is carried out starting from the hatching of chicken eggs to hatch. Meanwhile the cultivation process prioritizes the maintenance of chickens from chicks to adults [6]. Chicken as a type of poultry in the livestock industry is generally divided laying hens and broilers [7], [8]. Companies with a focus on laying hens or broilers can choose or even carry out both cultivation and breeding processes [9], [10]. Badan Pusat Statitik (BPS) noted that the chicken farming industry in Indonesia consists of 397 companies with 20,414 workers with an income of 15.92 trillion. BPS also notes that there are at least 143 chicken farming companies in Indonesia that focus on breeding processes [11].

Chicken breeding is carried out starting from the selection of brooders, feeding, maintenance patterns, mating, hatching eggs, and handling Day Old Chicken (DOC) [12]. The process of hatching eggs in the livestock industry is generally using an egg incubator [13]. The main obstacle in hatching egg using egg incubators is how to keep the temperature inside the incubator always at the range of 36°C - 40°C [14]. The development of egg incubator manufacturing has an increasing trend according to this problem.

There are 2 main problems to be solved in the development of egg hatching incubator recently. The problem is the ability to keep the temperature in an optimal range and transmit data for monitoring needs. One of the developments is sending temperature data to the egg incubator using the Global System for Mobile Communications (GSM) [15]. This study was explained that GSM media was used to control the incubator through the Short Message Service (SMS). This method is useful if the farm area that does not have an internet network. The study claims that the control system using an SMS gateway provides convenience in controlling. However, this method has weakness. The weakness is GSM technology which requires a fee for each control signal transmission. This increasing cost when applied to the livestock industry. Other research is needed to replace the GSM system into a radio frequency system with an adequate range. Another study focused on the development of an egg hatching incubator to maintain temperature using image processing and sensors [16]. Image processing system is used to monitor the condition of egg fertility based on color. The system is claimed to be able to help maintain temperature conditions at an optimal point. However, the use of cameras to monitor egg fertility will increase costs. The placement of the camera is inside the incubator. The placement can cause damage to the camera. Other studies related to sensor systems for temperature monitoring in incubators [17]. The research focuses on temperature monitoring using the internet using a computer. This research is claimed to help to monitor temperature parameters using Internet of Things (IoT) networks. This study did not discuss the accuracy results of the sensors used. The accuracy of the sensor in reading the temperature value will affect the performance of the actuator. This study does not explain the performance of the developed system. Other studies have also developed a control system based on the fuzzy method for incubating eggs [18], [19]. The research has a weakness because it uses software that is quite expensive. The software is used to show the results and performance of the system used. Another study discusses the IoT system in egg hatching incubators [20]. The study used Wide Fidelity (WiFi) devices in developing the prototype. The research is claimed to be able to streamline the steps of hatching eggs using the IoT system. To use this device, you need a WiFi network to connect to the internet. The ability to maintain the temperature in the optimal range between 36°C - 40°C is the main problem in egg hatching incubators. The sensor mismatch in reading the correct temperature will have an impact on determining the actuator control signal. Another problem occurs when the chicken coop and egg incubator are in different rooms. These problems require the delivery of data with good quality so that data monitoring occurs properly. The distance between the chicken coop and the control room is between 100m – 300m in poutlry. Research related to egg hatching incubators that are able to maintain temperature parameters, transmit monitoring data, and are cost-effective are interesting to study.

Problems in egg incubator are data storage, data transmission, accurate temperature reading, and temperature control. This study aims to develop an accurate reading and temperature control with monitoring system. The temperature data reading will be sent with LoRa (Long Range).

## METHODS

This research consist of developing a hardware and software for egg incubator. Main purpose of this research is how to make an accurate egg incubator with ability to transmit temperature reading. Data transmision must be low cost and can be impiment in wide range. This feature is needed for chicken poultry with seperate hatchry.

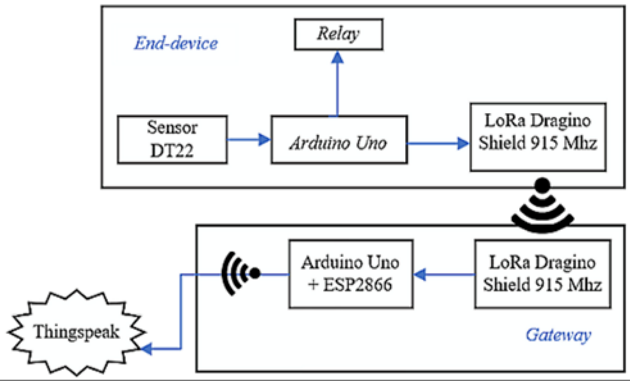


Figure 1. System Block Diagram

System consist of end device and gateway that can be shown in Figure 1. End devices consist of relays, microcontrollers, sensors, and LoRa transmitters. Relay is an actuator that is used to turn on and turn off the heating lamp. Microcontroller is used to control and generate logic signal for the egg incubator system. Sensor is used to read the temperature parameters inside the egg incubator. If the temperature is too cold, the microcontroller will send a signal to turn on heating lamp. If the temperature is too hot, the microcontroller will send a signal to turn off heating lamp. LoRa transmitter is used to transmit temperature data and actuator status to the gateway. Gateway consists of a LoRa receiver and a microcontroller. LoRa receiver is used to receive data from end devices. The microcontroller is used to give commands to receive data and send it to the IoT platform. End Device is used to read the parameters and condition in the egg incubator. Next process is sending all the data to the gateway. Placement of end device is in the hatcries while the gateway is in the control room.

Relay is connected with pin 4 of the microcontroller for the control signal. If pin 4 is "LOW" then the relay will cut off the electric current connection to the heating lamp. If pin 4 is "HIGH" then the relay will connect the electric current and turn on the heating lamp. This study use DHT 11 sensor to read temperature inside the edd incubator. This sensor connect with microcontroller pin 5. Reading result from the sensor will be send to microcontroller and microcontroller will process it.

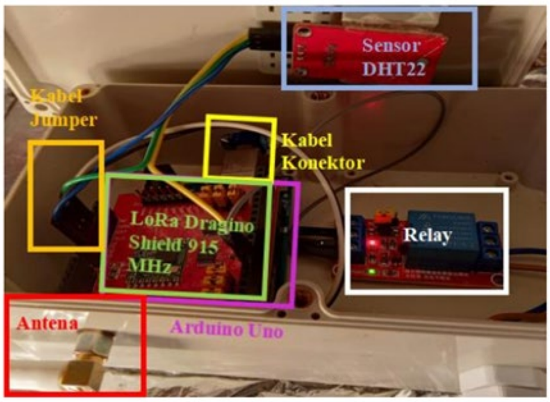


Figure 2. End Device System

The results of the manufacture of the end device are shown in Figure 2. The end device is located on the inside of the egg incubator device. The temperature sensor on the end device will merge with the space in the egg incubator so that the reading can be more accurate. The control system on the lights is also carried out by end devices. Lamps that use AC voltage will be controlled using relays to turn the lights on and off. LoRa delivery media is used to transmit temperature data so that it can be monitored by farm owners.

The gateway consists of 3 components, which is microcontroller, LoRa receiver and ESP8266. The microcontroller is used to give commands to the LoRa receiver to receive data from the LoRa transmitter on the end device and the ESP8266 to receive the internet network. Commands for LoRa receivers include commands to receive data, commands to adjust signal strength for data reception, and commands to send received data to the microcontroller memory. LoRa receiver serves to receive data sent from the end device. Both LoRa transmitter and LoRa receiver are the same 2 lora devices but used with different roles. RST on the LoRa pin is connected to pin 9 on the microcontroller. D0 on the LoRa pin is connected to pin 2 on the microcontroller. D1 on the LoRa pin is connected to pin 6 on the microcontroller. D2 on the LoRa pin is connected to pin 7 on the microcontroller. D5 on the LoRa pin is connected to pin 8 on the microcontroller. That configuration is used to make end device system in this study.

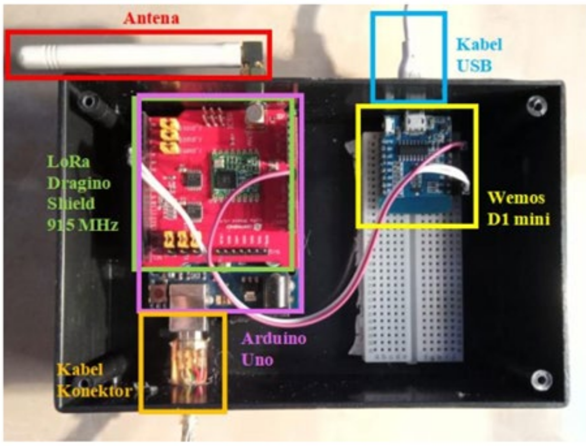


Figure 3. Gateway System

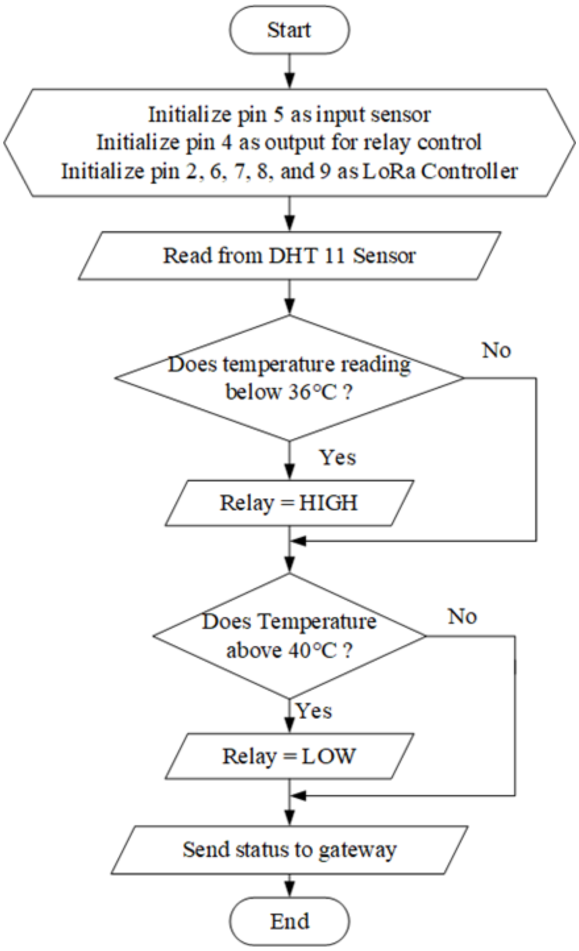


Figure 4. End Device Program Flowchart

The results of making the gateway device are shown in Figure 3. The location of the gateway is in a different control room from the end device. This is very important considering that the gateway requires a WiFi network that is not located at the end device location. The distance between the egg incubator located in the cage and the control room of the farm ranges from 100m – 300m.

The program flowchart for the end device is shown in Figure 4. The program starts by initializing the microcontroller pins. First step microcontroller will read the temperature data from the DHT 11 sensor. If the temperature data is below 36°C, the microcontroller will send a "HIGH" signal to relay the mercury lamp. The mercury lamp will increase the temperature in the egg incubator to a 40°C. When the temperature is above 40°C, the microcontroller will send a "LOW" signal to the microcontroller to turn off the mercury lamp. When the lamp is on but the temperature is not above 40°C, the lamp condition will not change with the initial state on. After turn off the lamp because of the temperature is above 40°C. The lamp will continue to turn off until the temperature is below 36°C. After the temperature control is carried out properly, all relay statuses and temperature readings will be sent to the gateway via the LoRa transmitter. This scenario is implemented in end device.

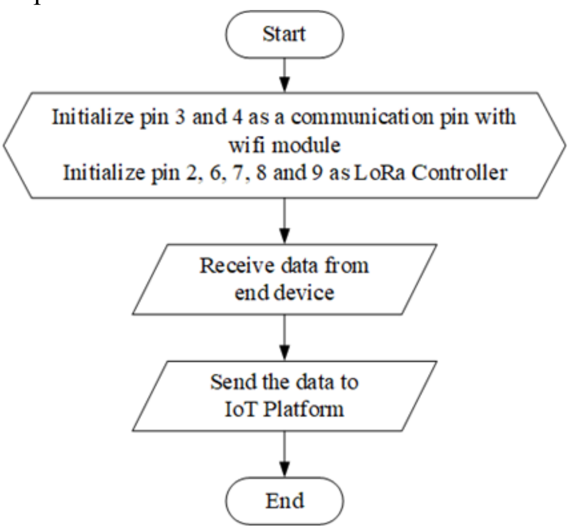


Figure 5. Gateway Program Flowchart

The gateway program flowchart is shown in Figure 5. Data is sent to the IoT platform with the aim of recording data on temperature conditions and mercury lamp status. The IoT platform used in this research is thinkspeak. The data sent on the IoT platform will be displayed into a graph so that the movement of system performance can be seen from its characteristics.

$$err = \left|\frac{ds - da}{da}\right| x\ 100\% \qquad (1)$$

$$acc = 100 - err \qquad (2)$$

System will then be tested for reliability by measuring temperature parameters, data transmission distance, receiving signal strength, and overall system performance. Sensor reading performance will be measure by calculating $err$ and $acc$ in fomula 1 and 2. In formula 1, $ds$ means data capture from the sensors, $da$ means actual data capture from thermogun.

## RESULT AND DISCUSSION

After the end devices and gateways have been successfully created, the next step is to test the devices. Tests are carried out to see the performance of the prototype. Focus of the research are temperature data, distance data from data transmission, receiver signal strength data, and overall system testing data. All of this data will be used to see if the system can maintain temperature parameters at the optimal point, transmit data over a distance of up to 300m, and test the quality of data transmission on the IoT platform. Research result explain the performance of whole system.

Table 1. Temperature sensor data testing

| Data Sensor | *Thermogun Value* | *err* | *acc* |
|---|---|---|---|
| 36,17°C | 36,04°C | 0,36% | 99,64% |
| 37,11°C | 37,05°C | 0,16% | 99,84% |
| 38,09°C | 38,10°C | 0,02% | 99,98% |
| 38,94°C | 39.08°C | 0,35% | 99,65% |
| 40.25°C | 40.00°C | 0,62% | 99,38% |

Testing data for temperature readings in the egg hatching incubator are shown in Table 1. The temperature sensor data was obtained from calculating the average value of the sensor output for 10 minutes. The timing of 10 minutes is based on the temperature change that is not too significant at that time. The amount of data obtained to calculate the average value of each temperature variable is 100 data. So it is known that the sampling used to get the data in TABLE 1 is 6 seconds. While the data from the Thermogun is the final value from direct observations. Based on the data in Table 1, the average percentage error for temperature data at 36.04°C is 0.36% with an accuracy of 99.64% from taking 100 test data, the average percentage error at 37.05°C is 0. .16% with an accuracy value of 99.87% from taking 100 test data, the average percentage error of 38.10°C is 0.02% with an accuracy value of 99.98%, the average percentage error temperature 39.08°C is 0.35% with an accuracy value of 99.65%, the average percentage error of temperature 40.00°C is 0.62% with an accuracy value of 99.38%. From all these data, the average percentage error for temperatures from 36°C - 40°C is 0.30% and the average accuracy is 99.69%. Based on the analysis value, temperature sensor works well to measure the room temperature in the egg incubator. The results of the data obtained are better than previous studies. Selection of sensors and sampling of data collection are things that must be considered.

Table 2. Data Communication Trough Distance

| Distance | Status | Successful data receive | Fail data receive |
|---|---|---|---|
| 50m | data receive | 100 | 0 |
| 100m | data receive | 100 | 0 |
| 150m | data receive | 100 | 0 |
| 200m | data receive | 100 | 0 |
| 250m | data receive | 100 | 0 |
| 300m | data receive | 100 | 0 |

Testing data on LoRa communication is shown in Table 2. Testing of data transmission on distance is carried out with a distance range of 50m – 300m. This is based on the distance from the egg incubator location to the setting room which is in that distance range. From the test results obtained, it is known that the data is well received for the distance range of 50m – 300m. The data sent for this test is the temperature data and the status of the mercury lamp. The data was sent 100 times and reviewed how the data was received. This delivery uses end devices and gateways according to the previous explanation. Based on these results, the device is able to transmit data properly via LoRa communication to the control room.

Tabel 3. Receive Signal Strength Indicator (RSSI) data from transmitter

| No | *RSSI (dBm)* | | | | | |
|---|---|---|---|---|---|---|
| | *50m* | *100m* | *150m* | *200m* | *250m* | *300m* |
| 1 | -104 | -106 | -108 | -115 | -118 | -120 |
| 2 | -102 | -110 | -113 | -113 | -119 | -114 |
| 3 | -102 | -111 | -106 | -114 | -118 | -118 |
| 4 | -104 | -111 | -110 | -108 | -117 | -117 |
| 5 | -105 | -111 | -111 | -117 | -119 | -118 |
| 6 | -103 | -111 | -111 | -116 | -116 | -119 |
| 7 | -105 | -111 | -111 | -116 | -118 | -120 |
| 8 | -104 | -110 | -111 | -116 | -117 | -118 |
| 9 | -105 | -110 | -111 | -116 | -118 | -111 |
| 10 | -103 | -111 | -111 | -116 | -119 | -113 |

The results of the Receive Signal Strength Indicator (RSSI) measurement to see the signal reception strength from the LoRa receiver are shown in Table 3. Based on the data in TABLE 3, transmission at a distance of 50m has the best signal strength quality. Signal strength using LoRa devices at this distance ranges from -102dBm to -105dBm. Signal strength in this range is classified as medium. It is based on the LoRa documentations published by the LoRa developers. Delivery on the medium range has no problems in implementing it. Other data that can be considered in TABLE 3 is the data obtained, for the farthest communication distance. At this distance, the RSSI range is between -111dBm to -120dBm. This range is classified as a weak signal according to the standards in the LoRa documentations. Although relatively weak, data transmission is still possible for a distance of 300m. An error that may occur due to a weak signal is a failure to transmit data. However, the potential for data received to be incomplete or corrupted cannot occur. This is because LoRa has been equipped with a security system so that if the data is damaged or incomplete, the data will not be accepted.

Tabel 4. Whole System Performance Testing

| No | *Temp Value Send* | *Status* | *Temp Value Receive* | *Lamp Condition* |
|---|---|---|---|---|
| 1 | 36,23°C | data receive | 36,23°C | Turn on |
| 2 | 36,82°C | data receive | 36,82°C | Turn on |
| 3 | 37,75°C | data receive | 37,75°C | Turn on |
| 4 | 38,38°C | data receive | 38,38°C | Turn on |
| 5 | 38,97°C | data receive | 38,97°C | Turn on |
| 6 | 39,53°C | data receive | 39,53°C | Turn on |
| 7 | 40,10°C | data receive | 40,10°C | Turn off |
| 8 | 39,64°C | data receive | 39,64°C | Turn off |
| 9 | 39,32°C | data receive | 39,32°C | Turn off |
| 10 | 38,37°C | data receive a | 38,37°C | Turn off |

The test data for the overall system scenario on the end devices and gateways are shown in Table 4. Based on the data in Table 4, the system is working as planned. When the temperature value is below 36°C, the mercury lamp will light up. Initial data is taken when the temperature reaches a value below 36°C so that in data 1 to data 6 the lamp condition is on. Then when the temperature value is above 40°C, the mercury lamp will be turned off automatically by the microcontroller. This phenomenon is seen in the 7th data in Table 4. The mercury lamp will turn off until the temperature value reaches a point below 36°C. The data in Table 4 is taken at a distance of 300m to transmit data. The furthest distance is used so that the worst case scenario if the system is used at the maximum limit can still work well. The status of receiving data in Table 4 shows that the data is well received and there is no data that is damaged due to data transmission that is far away. Based on the data presented in Table 4, it was concluded that the end device managed to regulate the room temperature in the egg incubator automatically.

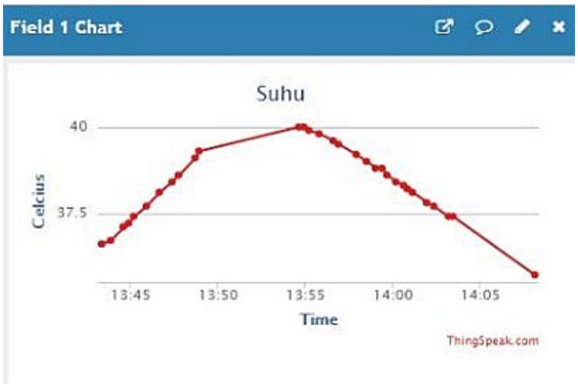


Figure 6. Chart in IoT Platform Thinkspeak

The results of sending data in Table 4 are recorded on the IoT platform thinkspeak with the results shown in Figure 6. Figure 6 shows that the data was successfully sent to the IoT platform from the gateway. The gateway sends data using an internet connection on a WiFi network and is successfully delivered to the IoT platform. Data transmission on the IoT platform can be used to record data so that the characteristics of the temperature control can be seen properly.

Comparing with another paper. Our System is cheaper but still solve the monitoring problem in egg incubator. Our IoT concept is from gateway which controll room already has internet network.

## CONCLUSION

Based on the results of device design, device implementation, and data collection, it can be concluded that the device works well. The device is able to maintain the temperature in the egg incubator in the range of 36°C - 40°C. Temperature readings with a range of 36.04°C, 37.05°C, 38.10°C, 39.08°C, and 40.00°C have an accuracy of 99.63%, 99.83%, 99 ,97%, 99.64%, and 99.37%. The heating function on the mercury lamp is able to heat the incubator room and will turn off when the temperature value read by the sensor is above 40°C. LoRa which is used to communicate between the incubator and the gateway works well at a distance of 50m – 300m with the status of the data being sent properly without any data defects. The data sent is well received at a distance radius of 300m with an average signal strength of -117dBm. Data transmission to the IoT platform through the gateway is well recorded. From the research conducted, it can be concluded that the device made is able to maintain the temperature value in the egg incubator well.

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