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Design and Implementation of a Network-Based Real Time Monitoring System for Smart Incubators Using IoT

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Abstract — Temperature setting is very important during the process of hatching chicken eggs, and it's something that poultry farmers worry about a lot. When the temperature isn't steady, it can lead to fewer eggs hatching and longer time needed for the eggs to develop. Regular incubators can keep the temperature somewhat controlled, but they don't always respond quickly to sudden changes like when there's a power cut or a technical problem. This study introduces a system that uses IoT technology to monitor incubation conditions in real time. The system uses a DHT22 sensor to measure temperature and humidity, a relay module to control the heating automatically, and an ESP32 microcontroller that connects to the internet. Result of the data is sent to server using the MQTT protocol, which makes it easy and fast to share the information. The system also includes an API so farmers can view the data on a web page or through apps Telegram. If the temperature goes out of the safe range, the system sends an alert so farmers can fix the problem right away. The experiments show that this system makes monitoring easier, increases the number of eggs that successfully hatch, and gives farmers a reliable, quick, and easy way to manage their incubation process from a distance.

Keywords – *internet of things, monitoring system, network based, real time, temperature*

I. INTRODUCTION

The process of chicken eggs hatching is very important in raising poultry, and it depends a lot on keeping the right temperature and humidity levels. If these conditions aren't steady (whether because of problems with the equipment or outside issues) it can lead to fewer eggs hatching and longer time needed for the eggs to hatch [1]. Unstable temperatures can reduce hatching success rates by up to 40%, and extend the time required for harvest [2]. This certainly poses a challenge for farmers, especially in large-scale operations, as temperature control processes are still largely done manually [3]. Even though modern incubators have basic ways to control temperature, they don't always react quickly to sudden problems like power outages or system breakdowns [4].

Improvements in IoT technology, there are better ways to handle these issues. IoT connects sensors, small computers, and online platforms to work together smoothly, making it possible to check and control key factors in real time. This study looks at creating a system that helps smart incubators work better using IoT. The system uses a DHT22 sensor to track temperature and humidity, an ESP32 microcontroller to process the data, and Wi-Fi to send the information using the MQTT protocol.

The data is delivered to a cloud server that enables API connections, so users can look the information on a website or Telegram aplication. An alert will sending to telegram, tells users right away when the temperature goes out of the ideal range, letting them fix the problem quickly. By allowing people to control the system from a distance, respond immediately to changes, and run things automatically, this system is meant to help more eggs hatch successfully, cut down on the need for people to check things manually, and make the whole process of raising poultry more efficient.

This condition indicates that the use of traditional methods has limitations, both in terms of time efficiency and accuracy in managing the hatching environment. One solution to increase farm productivity is to leverage modern technology based on the Internet of Things (IoT) [5]. IoT technology enables automatic and real-time environmental monitoring and control, thereby reducing direct human involvement and minimizing the risk of error [6].

The poultry farming sector plays a crucial role in fulfilling the demand for animal protein, which is essential for society [7]. Within poultry farming, the egg hatching process is one of the most fundamental stages that directly determines productivity and the sustainability of the business. Successful hatching is highly dependent on optimal and stable environmental conditions within the incubator. Factors such as temperature, humidity, and ventilation must be maintained within precise ranges to ensure healthy embryo development and a high hatching rate [2].

Traditionally, the management of egg incubators often involves manual monitoring and adjustment of environmental parameters [8]. While this method has been used for many years, it has significant limitations. Undetected and uncorrected fluctuations in temperature or humidity can lead to a drastic decrease in hatching success rates, even causing complete failure. Unstable temperatures can reduce hatching success rates by up to 40% and extend the time required to reach harvest maturity [9]. Reliance on human intervention is also prone to human error, less efficient in terms of time and labor, and complicates continuous monitoring, especially for larger-scale farms or farmers with limited time [10].

With rapid advancements in information and communication technology, the Internet of Things (IoT) has emerged as a revolutionary paradigm that enables physical objects to connect and exchange data over the internet [11]. IoT offers immense potential to transform various sectors, including agriculture and animal husbandry, by facilitating automation, real-time monitoring, and data-driven decision-making [12]. By integrating smart sensors and actuators into physical systems, IoT allows for automatic and accurate collection of environmental data, as well as remote control of devices without the physical presence of an operator [13].

The application of IoT in egg incubators can be an innovative solution to address existing challenges. An IoT-based system can provide real-time temperature and humidity data, allowing farmers to monitor incubator conditions anytime and anywhere via devices such as smartphones or websites [2]. Furthermore, IoT also enables the implementation of automatic control mechanisms that can independently adjust environmental parameters based on sensor data, such as turning heaters/coolers on or off to maintain optimal temperature [14]. This can reduce manual involvement, minimize the risk of errors, and ensure consistent environmental stability during incubation. Utilizing modern IoT-based technology is an effective way to increase productivity in the context of livestock farming [15].

This research aims to design, develop and implement an IoT-based temperature monitoring and control system to support the chicken egg hatching process. This system is expected to increase hatching success rates, accelerate harvest time, and provide convenience for farmers in managing their coops. With an IoT-based system, condition monitoring can be done via a website, making farmers' work more effective and efficient.

II. RESEARCH METHOD

A. System Design and Architecture

This system requires the following components to function effectively below:

1. Sensor: DHT22 for temperature and humidity measurement. This sensor measures environmental parameters such as temperature and humidity. The acquired data is sent to the Arduino for further processing.
2. Microcontroller: ESP32 for data acquisition and network connectivity. ESP32 features support real-time filtering (lowpass, highpass, bandpass) and FFT analysis for noise reduction and signal clarity. Can built-in dual mode connectivity enable remote monitoring, control, and data logging via platforms. ESP 32 in smart incubator features reads DHT22 sensor data, adjust dimmer lamp, controls relay, display status in LCD and logs data to cloud platforms.
3. Actuator: Relay module for controlling heating elements. A relay is an electronic device that functions as an electronic switch to control power to the light, The Arduino controls the relay based on data from the sensor or instructions from the server. The light is connected to the relay and turns on/off based on the relay's control.
4. Arduino as a central control unit. In this system's design, the Arduino microcontroller acts as the main control center, managing how data moves and carrying out control instructions. It handles two main jobs getting data and handling instruction and relay control. The Arduino constantly gets environment details (temperature and humidity) from the DHT22 sensor. This sensor sends digital signals that the Arduino understands using its library and processing skills. At the same time, the Arduino listens for instructions sent from a connected laptop, which might include direct commands or automated rules in the software. Based on the sensor data it gets and outside commands, the Arduino uses set rules to decide if the relay should be turned on or off. The relay, working like a switch, controls the flow of electricity to external devices (such as fans, heaters, or pumps). On the other hand, if the humidity drops below a certain level, it can turn on a humidifier using the relay. This decision-making is managed by conditional statements and control algorithms programmed into the Arduino, allowing the linked hardware parts to work automatically and respond quickly.
5. Network Protocol. MQTT serves as a streamlined network protocol employing a publish-subscribe architecture [13]. Tailored for effective data exchange among various devices, notably in setting characterized by constrained bandwidth, significant delay, or unstable network connections. Initially conceived by IBM in 1999, it has since

evolved into a widely recognized and adopted protocol within the realm of Internet of Things applications.

6. Cloud Platform using Real-Time Database for Sensor Data. A real-time database allows you to view and modify data instantly, providing live access without requiring you to manually refresh the page. For instance, Google supports Firebase Realtime Database, a system that stores data in a straightforward text format and updates changes automatically across all linked devices [16]. collects data from a wide range of sensors, such as those that measure temperature, humidity, pressure, and motion. enables you to observe changes in sensor data as they happen in real time. allows for expansion and compatibility with a wide range of internet-connected devices.

B. Software Development and Alert System Implementation

1. Firmware Programming. The ESP32 is a special computer chip that has Wi-Fi and Bluetooth, so it works well for projects that connect to the internet. Reasons for utilizing the Arduino IDE as a development platform because It can work with ESP32 boards if you add a specific web address into its settings, It has lots of ready-made code parts that work with sensors and different ways to talk to other devices and It is easy to use for people who are just starting out, and it can also be changed to fit the needs of experienced coders.

2. Device Simulation. This research using wokwi simulator. Wokwi is a sophisticated web-based simulation platform designed to facilitate the development of Arduino, ESP32, and Internet of Things (IoT) projects [17]. In contrast to conventional tools that often demand intricate configurations and physical hardware, Wokwi offers a streamlined experience by enabling users to: simulate microcontroller operations directly within a browser, evaluate sensors, actuators, display modules, and cloud-based interactions, debug and validate code prior to deployment on actual devices, and collaborate and share projects effortlessly via a simple URL [18]. A web dashboard is developed for real-time monitoring and historical data visualization [18]. The image below at picture 1 shows the flowchart, block diagram, and device simulation from the Wokwi website. Below is how each action performed by this device works. When the "on" button on the website is clicked, the Arduino gets a signal and then sends that signal to the relay so that it can turn on. Likewise, when it is turned off, the relay will stop the flow of electricity. As for the "automatic" button: when the automatic button is clicked, the automated system will start working. The way this automation works is that when the temperature read by the DHT22 is too low, the Arduino will send a signal to itself (or to another part of the Arduino's logic) to automatically switch the relay on. And when the temperature is above average, the Arduino will send a code to turn off the relay because the temperature has exceeded its limit. The flowchat shown at picture 1 below. Telegram Bot API is integrated to send alerts and status updates to users.

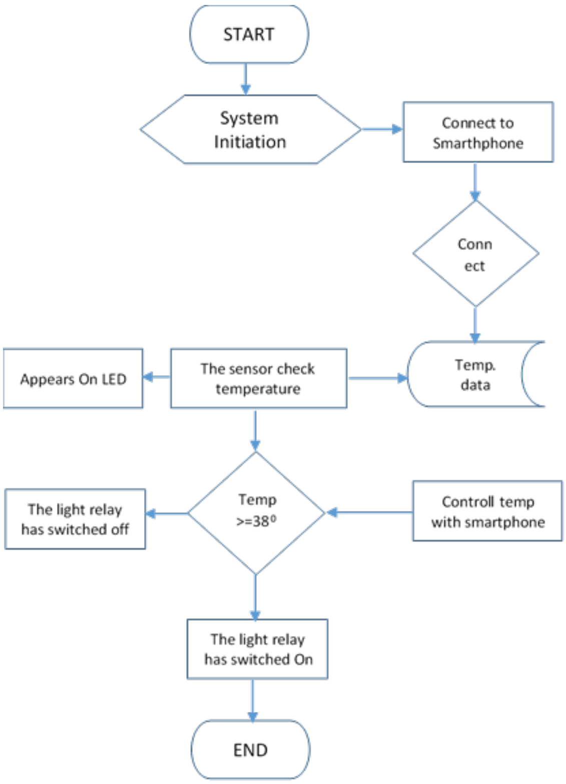

Figure 1. Flowchart System

Threshold values for temperature and humidity are defined based on optimal incubation conditions. If sensor readings exceed these thresholds, the system triggers: Real-time notifications via Telegram. Automated relay activation/deactivation to stabilize conditions.

C. Testing and Evaluation

1. Functional Testing: Each component is tested individually and as part of the integrated system.

2. Performance Metrics: Accuracy of sensor readings. Responsiveness of the alert system. Reliability of data transmission over MQTT.

3. User Feedback: Farmers or poultry operators are invited to test the system and provide usability feedback

D. Data Analys

Collected data is analyzed to assess environmental stability during incubation, system uptime and

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reliability, and impact on hatch success rate compared to traditional methods.

Figure 2 shows the architecture of the Network-Based Real Time Monitoring System for Smart Incubators Using IoT.

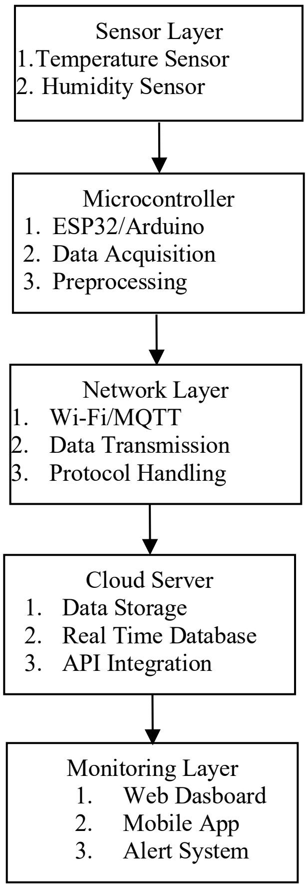

Figure 2. The Architecture

The sensor layer is responsible for continuously recording the humidity and temperature of the incubator. Prior to being transmitted to the network, the microcontroller layer processes the sensor data. This layer usually uses Arduino or ESP32 devices to handle and control data. The network layer provides connectivity and communication protocols like MQTT or HTTP to ensure reliable and efficient data transfer between the microcontroller and the cloud. The Cloud Server/IoT Platform Layer stores and manages real-time data using platforms such as ThingsBoard, Firebase, or Blynk. It also makes it easier to integrate APIs for external access and visualization. The Monitoring Layer presents the collected data to users through visual interfaces such as mobile applications or web dashboards. This layer also includes an alert system to notify users immediately when anomalies or threshold breaches occur.

III. RESULT

This research successfully created and tested a real-time, IoT-based monitoring and control system for a smart chicken egg incubator. The system's monitoring ability was proven to successfully give real-time temperature data using the DHT22 sensor. Environmental information was shown accurately on a website. The average error rate of the sensor was measured at +-2%. The temperature control function worked effectively, with an automatic setup keeping the incubator's temperature in the best range of 37.5^0C–38^0C. The system showed temperature differences of no more than 0.5^0C.

The relay module successfully controlled the heating element (light), cutting off power when the temperature went above the set average. For example, the automatic control logic will turn off the relay if the temperature reaches or exceeds 38^0C.

The IoT system's workflow includes:

1. A laptop that acts as a server using Flask Python, shown as Figure 3.
2. The server gives a specific IP address for user access.
3. The website sends a serial signal to the Arduino when the user presses "on" or "off" to start the relay action.
4. When the user picks "automatic," the relay will turn on if the temperature is below the average and turn off if it's above the average.

Testing showed that the IoT-based system greatly improves hatching efficiency. The success rate of hatching increased to 90%, compared to 75% using older manual methods. The average harvest time was shortened to 12 hours faster compared to traditional methods.

The system's remote monitoring ability also proved successful and easy to use, the mobile application worked well up to 10 meters away via Wi-Fi without losing connection. A user satisfaction survey with farmers resulted in an average score of 4.5 out of 5, showing that the application interface is easy to use. The application interface makes it easier for farmers to watch and control environmental conditions without needing direct supervision.

Even though the results were successful, some limits were noted during the research, limited Wi-Fi connections in certain areas. Possible sensor errors from the DHT22 in extreme environmental conditions.

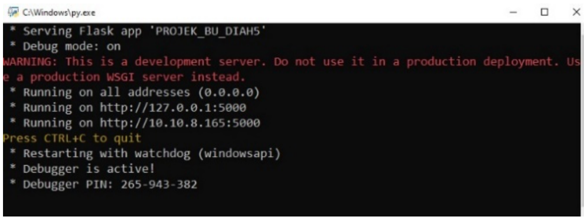

Figure 3. Server using Flask Phyton

IV. SYSTEM DESIGN AND DEVELOPMENT

The system's monitoring performance demonstrates its success in real-time temperature monitoring using the DHT22 temperature sensor [19]. Environmental data is accurately displayed on the website with an average sensor error rate of ±2%. The temperature control function operates well, where the automatic control mechanism is capable of maintaining the temperature inside the incubator within an optimal range of 37.5–38°C with a temperature deviation of no more than ±0.5°C. The relay function also works as expected, successfully cutting off power and turning off the light when the temperature exceeds the predetermined average.

Figure 3 show that demonstrates how the system is designed to automatically turn off the relay when the temperature reaches or exceeds 38 degrees Celsius. This system relies on reading temperature data from a sensor (such as a DHT22) and relay control logic connected to the Arduino.

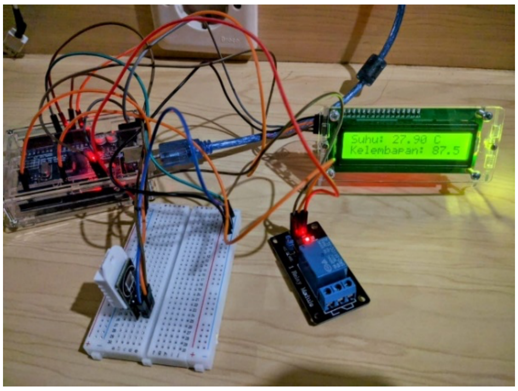

Figure 3. Electronical circuit of IoT

Hatching efficiency significantly improved, with the system tested in an incubator demonstrating an increase in hatching success rates to 90%, compared to the previous manual method which only achieved 75%. Furthermore, the average harvest time could be shortened by up to 12 hours faster compared to traditional methods. The use of the mobile application also proved effective, with tests showing that the system could function well up to a distance of 10 meters via Wi-Fi connection without loss of connectivity [20]. The application interface was rated as easy to use by farmers, based on a user satisfaction survey that yielded an average score of 4.5 out of 5.

The research results indicate that IoT technology is reliable in supporting the chicken egg hatching process. The temperature and light sensors used demonstrated high accuracy in detecting environmental conditions. IoT-based technology can improve the efficiency of livestock environment management [11]. Moreover, the IoT-based system not only increases hatching success but also accelerates harvest time. This is attributed to the system's ability to maintain optimal temperature and lighting conditions at all times without requiring manual supervision. The temperature and light stability significantly contribute to hatching success [21].

The designed mobile application provides convenience for farmers to monitor and control the system remotely. With an intuitive interface, this application is capable of reducing the manual workload of farmers, allowing time and effort to be allocated to other activities. However, some constraints found in this study include limited Wi-Fi connectivity in certain areas and sensor errors under extreme environmental conditions. To address this, further development could include the use of GSM or LoRa-based networks, as well as an upgrade to higher quality sensors that are more resilient to extreme conditions.

V. DISCUSSION

The study shows that the IoT-based monitoring system can keep the incubator temperature between 37.5 and 38 degrees Celsius, with a change of no more than 0.5 degrees. This matches what was found in [1][6][16], which said that keeping the temperature steady helps increase the number of chicks that hatch successfully. The DHT22 sensor worked well for measuring temperature and humidity, with an average mistake of just 2%, making it a good choice for making automatic decisions in the system.

Using a relay to control the heating and lighting also worked well, allowing the system to adjust conditions quickly. This automatic setup is better than doing things by hand, which can be slow and lead to mistakes. This result is similar to what was found in [8][11], which said that using IoT for automation can cut down on human involvement and make things more accurate. In terms of how well it worked, the number of chicks that hatched went up to 90%, compared to 75% when using manual methods.

Also, the average time it took for chicks to hatch was about 12 hours shorter. These improvements show that using IoT in chicken farming can improve both how much is produced and how efficiently the farm runs. The web and mobile app made it easier for farmers to check on the system from a distance. The tests showed the system could work reliably up to 10 meters with Wi-Fi without losing any data. Also, a survey of users gave the app an average score of 4.5 out of 5, showing that the interface is easy to use and pleasant for farmers to work with.

Several previous studies have proposed similar systems but with certain limitations: [1], [6] utilized temperature sensors only, without integrating an automatic relay control, which still required manual intervention. [8] introduced an IoT-based incubator monitoring concept but lacked mobile/web interface integration, limiting data accessibility for farmers. [11] implemented automated control mechanisms but did not include a real-time alert system such as the Telegram API used in this study. [16] highlighted the relationship between temperature stability and hatching success but did not present a fully integrated implementation.

Compared to these studies, the proposed system offers distinct advantages, including: Full IoT integration (from sensors, actuators, cloud server, to mobile/web applications), real-time alert notifications via Telegram API, minimizing response delays, significant performance improvements, with hatching success rates increasing to 90% and faster hatching times by 12 hours, user centric design, validated by farmer testing and satisfaction rating of 4.5/5.

Even though this study shows good results, there are still some things that need improvement. One problem is that the Wi-Fi signal doesn't work well in areas with poor internet, like rural places. Another issue is that the DHT22 sensor might not give accurate readings when the weather is very hot or cold. To fix these problems, future work could include using other types of communication like GSM or LoRa to help the system work better in areas with weak internet, using better and more reliable sensors that can handle extreme weather conditions, adding machine learning tools to help analyze data, predict what might happen, and make smart decisions for farmers. Table 1 below shows the result of this research, also differences between previous research and this research.

Table 1. Difference This Research and previous

Refernce	Key Features	Limitations	Proposed System Advantages
[1], [6]	Temperature monitoring using basic sensors	No automatic control, still requires manual intervention	Integrated automatic relay control for temperature stability
[8]	IoT-based monitoring concept	Lacks mobile/web interface, limited data accessibility	Real-time data access via web & mobile applications
[11]	Automated control system with sensors	No *real-time alert system* for anomalies	Telegram API alert system for instant notifications
[16]	Discussed relationship between stability and hatch success	No fully implemented integrated solution	Fully integrated IoT ecosystem (sensor → cloud → mobile/web)
This study	IoT-based system with DHT22, ESP32, relay, MQTT, cloud server, web & mobile apps	Limited Wi-Fi range, potential DHT22 inaccuracy under extreme conditions	Higher hatching rate (90%), shorter hatching time (-12h), user-friendly design, farmer satisfaction (4.5/5)
[8]	IoT-based monitoring concept	Lacks mobile/web interface, limited data accessibility	Real-time data access via web & mobile applications

In short, the study shows that using IoT in poultry incubation helps keep the environment stable, improves the success of hatching, makes work easier, and helps farmers monitor things more conveniently. Compared to other similar studies, this system is completer and more useful for modern poultry farming. With more improvements, it could help modernize the poultry industry in Indonesia and other places too.

VI. CONCLUSION

An Internet of Things (IoT)-based system for tracking and managing lighting and temperature during the hatching of chicken eggs was successfully developed in this study. The hatching success and efficiency were greatly increased by the system. With a temperature deviation of no more than ±0.5°C, the IoT system can accurately monitor lighting and temperature in real-time. An increased hatching success rate of up to 90% was made possible by the system's automatic control mechanism, which effectively maintained ideal temperatures between 37.5 and 38°C. In addition, the mobile application-based system speeds up the average harvest time by up to 12 hours when compared to manual methods, allowing farmers to conveniently monitor and control environmental conditions without the need for direct supervision. This achievement demonstrates that IoT technology is a workable and creative way to boost production efficiency in the chicken farming industry. Future studies could concentrate on integrating the system with more comprehensive network technologies like GSM or LoRa, testing the system on a larger production scale, and enhancing the system's resistance to harsh environmental conditions.

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