

# Effectiveness of Telemetry Monitoring and Automatic Control Systems for Chicken Coops Based on IoT

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## ABSTRACT

The management of environmental factors such as temperature, humidity, and ammonia levels are critical to the health and productivity of broiler chickens. Yet, many farmers still rely on manual monitoring, which is inefficient and prone to human error. Therefore, adopting the IoT-based telemetry systems can enhance monitoring accuracy and efficiency in poultry farming. This article evaluates the effectiveness of Internet of Things (IoT)-based telemetry systems in automating and monitoring poultry environments. By integrating various microcontrollers such as Arduino, NodeMCU ESP32 and Wemos D1 Mini with advanced sensors (DHT11/22, MQ-13 and ultrasonic sensors), these systems provide real-time data visualisation and automatic actuator control. Research methods include the waterfall development model, which involves prototyping models, utilising control logics like threshold, fuzzy tsukamoto, and Gaussian Naive Bayes. Results indicate the IoT implementation can maintain the coop's microclimate within ideal ranges (28°C–34°C for temperature), reduce energy consumption by up to 25%, and significantly lower mortality rates by maintaining ammonia levels below 20 ppm. The integration of telemetry via web dashboards, Blynk, and Telegram allows farmers to monitor and control their livestock remotely, enhancing operational efficiency and productivity.

**KEYWORDS:** *Automatic Control, IoT, Telemetry Monitoring.*

## 1. INTRODUCTION

The poultry industry, particularly broiler chicken farming, holds a vital strategic position in fulfilling the global and regional demand for high-quality animal protein. Broiler chickens are specifically cultivated for meat production due to their superior genetic traits, including rapid growth rates and high feed conversion efficiency, which allow them to reach harvest-ready weights within a remarkably short period of four to six weeks. In Indonesia, the demand for poultry products continues to rise alongside the growing population and increasing awareness of nutritional needs, making this sector a primary pillar of the national economy and food security roadmap. However, the economic success and sustainability of poultry farming are heavily dependent on the management of environmental factors within the coop, as broilers are highly sensitive creatures that require precise microclimate regulation to thrive [1].

Ideally, a chicken coop must maintain a stable and conducive environment that aligns with the physiological needs of the birds throughout their various growth stages. Key environmental parameters include temperature, humidity, and air quality, specifically the concentration of hazardous gases like ammonia. For young chicks (DOC), the optimal temperature typically high, around 34°C, and gradually decrease as they age to approximately 21°C–23°C for adult birds. When these conditions are not met, chickens experience significant physiological stress. High temperatures and extreme heat stress can lead to "panting", a condition where chickens keep their mouths open to dissipate heat, leading to increased water consumption, reduced feed intake by up to 25%, and metabolic disturbances that severely stunt growth and increase mortality rates. Conversely, temperatures that are too low force the birds to divert energy from meat production to maintaining body heat and feather growth, resulting in poor weight gain and suboptimal performance [2].

Beyond temperature, the accumulation of ammonia gas (NH<sub>3</sub>) presents a silent but deadly threat in poultry environments. Ammonia is a by product of the microbial decomposition of chicken waste (faeces), and its concentration can quickly escalate in poorly ventilated coops. High ammonia levels are not only characterised by a pungent

odour that irritates human caretakers but also cause severe health issues for the livestock. Exposure to ammonia levels exceeding the safe threshold of 20–25 ppm can result in irritation of the respiratory mucous membranes, conjunctivitis, corneal damage, and a weakened immune system, making the birds more susceptible to bacterial infections such as *E. coli* or viral diseases like Newcastle Disease (Tetelo). Furthermore, chronic exposure to ammonia significantly reduces body weight and overall productivity, directly impacting the farmer's profitability [3].

Despite the critical nature of these variables, traditional poultry management in many regions, including various villages across Indonesia, still relies heavily on manual monitoring and conventional practices. Farmers often perform physical inspections, checking temperatures based on personal estimation or simple thermometers, and manually operating fans or heaters. This manual approach is inherently inefficient, as it requires constant physical presence and is highly prone to human error [4]. Sudden environmental changes, such as sharp temperature spikes during the day or ammonia build up at night, often go undetected until it is too late, leading to delayed responses that can cause mass mortality and substantial financial losses. Additionally, the geographic isolation of some farms and the fact that many farmers have other occupations often prevent intensive, 24-hour supervision [5].

The emergence of the Internet of Things (IoT) and embedded system technology offers a transformative solution to these persistent challenges. IoT refers to a network of physical objects integrated with sensors, actuators, and microcontrollers that can communicate with each other and exchange data over the internet. In the context of "smart farming", IoT allows for the creation of an automated microclimate control system that operates continuously without human intervention. By utilising various sensors such as the DHT11 or DHT22 for temperature and humidity and the MQ-135 or MQ-7 for gas detection, a system can collect high-accuracy data in real-time. This data is then processed by microcontrollers like Arduino Uno, NodeMCU ESP32, ESP8266, or Wemos D1 Mini, which act as the "brain" of the system [6].

Effectiveness in this technological framework is achieved through telemetry and automatic control. Telemetry enables the remote measurement and transmission of data from the coop to the farmer's device, regardless of the distance. Through integrated web dashboards built with frameworks like Laravel and PHP or mobile platforms like Blynk, farmers can monitor the status of their coops from anywhere at any time. Furthermore, the system can be programmed with smart logic, such as threshold, fuzzy Tsukamoto, or Gaussian Naive Bayes to make autonomous decisions. For instance, if the temperature exceeds a set threshold, the system automatically activates exhaust fans; if ammonia levels rise, the ventilation is boosted; and if the coop becomes too cold, heating lamps are triggered via relays.

To enhance accessibility and response time, modern IoT co-op systems are increasingly integrated with instant notification services like Telegram bots. These bots send real-time alerts to the farmer's smartphone if parameters reach "danger" levels, allowing for immediate corrective action. Such automated frameworks have been shown to maintain environmental stability, reduce electricity consumption by up to 25% by only running devices when needed, and

significantly improve the quality and weight of the livestock [7].

This study aims to evaluate and implement an IoT-based telemetry monitoring and automatic control system designed specifically for broiler chicken coops. By bridging the gap between traditional practices and modern technological capabilities, this research seeks to provide a robust, cost-effective, and scalable solution that enhances operational efficiency, minimises production risks, and optimises the growth environment for chickens. The following sections will detail the design, hardware architecture, software logic, and the practical outcomes of implementing this smart farm system in a real-world poultry environment [8]. Through the integration of real-time monitoring and autonomous actuators, this research highlights the effectiveness of IoT in revolutionising small-to medium-scale poultry farming toward a more sustainable and productive future.

## 2. THEORETICAL BASIS

The development of an Internet of Things (IoT)-based telemetry monitoring and automatic control system for poultry farming is grounded in several intersecting domains of technology and biological science. This section outlines the fundamental concepts of IoT, telemetry, embedded systems, sensor technology, and the physiological requirements of broiler chickens that form the framework for this study [9].

### 2.1 Internet of Things (IoT) and Telemetry

The Internet of Things (IoT) is a transformative technology that enables physical objects to connect to the internet, allowing them to collect, exchange, and act upon data without direct human intervention. An IoT system typically consists of four layers: the sensing layer (sensors and actuators), the network layer (internet connectivity), the processing layer (microcontrollers and cloud servers), and the application layer (user interfaces like web dashboards or mobile apps). In poultry management, IoT facilitates "smart farming", where the coop environment becomes an intelligent ecosystem capable of self-regulation.

Closely linked to IoT is telemetry, a technology used to measure, record, and transmit data from remote or inaccessible locations to a central monitoring station. The term originates from the Greek words '*tele*' (far) and '*metron*' (measure), essentially meaning "measurement at a distance". In this research, telemetry allows farmers to receive real-time updates on coop conditions regardless of their geographical distance from the site, reducing the need for constant physical presence [10].

### 2.2 Embedded Systems and Microcontrollers

At the heart of any IoT implementation is the embedded system, a specialised computer designed to perform specific tasks within a larger mechanical or electrical system. These systems rely on microcontrollers to process sensor inputs and trigger actuator responses [11].

- **Arduino Uno R4 WiFi:** An advanced open-source platform that combines the processing power of the Renesas RA4M1 microcontroller with built-in WiFi and Bluetooth connectivity, making it ideal for IoT projects requiring high computation and seamless networking.

- Node MCU ESP32 and ESP8266: These are low-cost, low-power "System-on-Chip" (SoC) modules. The ESP32 is particularly noted for its dual-core processor, 520 KiB internal RAM, and integrated WiFi and Bluetooth, providing the robustness needed for real-time web server tasks [12].
- Wemos D1 Mini: A compact board based on the ESP8266 that provides 11 digital pins and WiFi support, offering an economical solution for small-scale automation. The ESP 32-bit microcontroller shows in Figure 1.

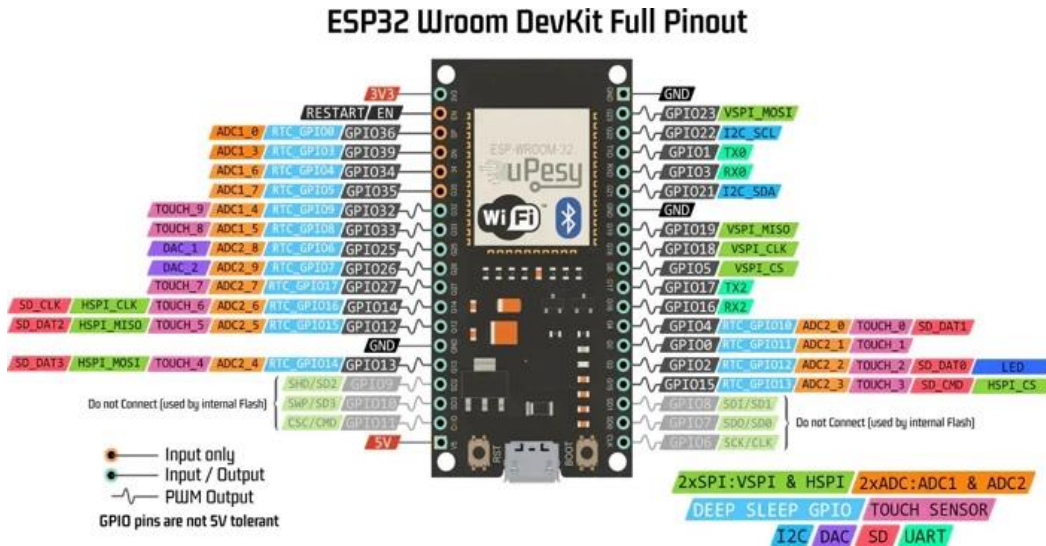


Figure 1: The ESP 32-bit microcontroller

### 2.3 Sensor Technology for Environmental Monitoring

To monitor the coop's microclimate, various sensors are utilised to convert physical parameters into digital signals.

- Temperature and Humidity (DHT11/DHT22 & BME280): The DHT11 and DHT22 are digital sensors that measure ambient temperature and relative humidity using capacitive and thermistor components. While DHT11 is popular for basic projects, the DHT22 offers a wider range and higher accuracy. The BME280 is a more advanced sensor that combines temperature, humidity, and atmospheric pressure sensing with high-resolution digital output [13]. Figure 2 shows the DHT11 sensor.

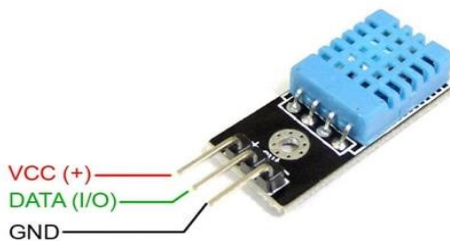


Figure 2: DHT11

- Gas Detection (MQ-135 & MQ-7): The MQ-135 is a hazardous gas sensor sensitive to ammonia (NH<sub>3</sub>), carbon dioxide (CO<sub>2</sub>), and benzene. It works on the principle of variable resistance; the resistance of its sensing material changes when exposed to specific gases, allowing for the calculation of concentration in parts per million (ppm). The MQ-7 is specifically used for carbon monoxide detection.
- Ultrasonic and Load Cells: Ultrasonic sensors measure distance by emitting sound waves, commonly used to

monitor feed levels in silos. Load cells paired with the HX711 module act as transducers to measure weight, enabling automated livestock weighing [14].

### 2.4 Control Actuators and Logic

An automatic control system requires actuators to execute changes in the environment based on sensor data. The relay is the most critical actuator in this context; it is an electromagnetic switch that allows low-power microcontrollers to control high-voltage devices like exhaust fans, incandescent lamps, and water pumps.

The "intelligence" of the system is defined by its control logic:

- Thresholding: A simple yet effective logic where actions are triggered when a parameter crosses a predefined limit (e.g., if Temp > 34°C, turn on the fan).
- Fuzzy Tsukamoto: A form of fuzzy logic that handles the uncertainty and "grey areas" of environmental data. It maps numerical sensor values into linguistic variables (e.g., "cold", "neutral", "hot") and uses IF-THEN rules to determine a smooth, non-binary output for actuators.
- Gaussian Naive Bayes: A machine learning classification algorithm based on probability. It calculates the likelihood of the coop environment being "ideal" or "bad" based on a training dataset, allowing for highly accurate autonomous decision-making [15].

### 2.5 Data Transmission Protocols and Platforms

To visualise telemetry data, various communication protocols and platforms are employed:

- MQTT (Message Queuing Telemetry Transport): A lightweight messaging protocol designed for low-

bandwidth, high-latency environments, using a publish/subscribe model.

- **HTTP/HTTPS:** Standard protocols for data transmission between the coop hardware and web servers.
- **Blynk:** A mobile IoT platform that allows users to create custom interfaces for monitoring and manual control via smartphones [16].
- **Telegram Bot:** An instant messaging interface that sends real-time notifications to farmers when environmental anomalies (like high ammonia) are detected.
- **Cloud Visualisation (Grafana & InfluxDB):** InfluxDB serves as a time-series database to store historical sensor data, while Grafana provides advanced graphical dashboards for long-term trend analysis.

### 2.6 Physiological Needs of Broiler Chickens

The ultimate effectiveness of these technologies is measured by how well they satisfy the biological needs of the livestock. Broiler chickens are meat-producing birds characterised by rapid growth. However, they lack sweat glands and are covered in feathers, making them highly susceptible to heat stress [17].

Temperature is one of the most critical environmental parameters in poultry farming, as it directly affects the physiological condition and productivity of chickens. The ideal temperature ranges from approximately 34°C for day-old chicks and gradually decreases to around 21°C for mature birds. Exposure to temperatures outside the optimal range can induce heat stress, characterized by panting behavior in which chickens keep their mouths open to release excess body heat. This condition may reduce feed consumption, disrupt metabolic processes, and negatively affect growth performance and overall health.

Ammonia (NH<sub>3</sub>) is a harmful gas produced from the decomposition of poultry manure and organic waste within the coop environment. Concentrations exceeding 20–25 ppm are considered hazardous and may lead to respiratory tract irritation, conjunctivitis, and decreased immune resistance in poultry. Prolonged exposure to elevated ammonia levels can also increase the susceptibility of chickens to infectious diseases, including Newcastle Disease (Tetelo), thereby reducing productivity and increasing mortality risk.

Humidity also plays a significant role in maintaining poultry comfort and environmental stability. The recommended relative humidity range for chickens is between 50% and 70%, which is considered the thermal comfort zone for optimal growth and health. Excessively high humidity limits the chickens' ability to dissipate body heat effectively, potentially leading to heat stress, while excessively low humidity may cause dehydration and respiratory discomfort. Therefore, maintaining balanced humidity levels is essential for ensuring animal welfare and improving poultry production efficiency.

By integrating these theoretical foundations, an IoT telemetry system creates a precision farming environment that maximises productivity while ensuring animal welfare.

## 3. METHOD

The methodology for implementing an Internet of Things

(IoT)-based telemetry monitoring and automatic control system in broiler chicken coops follows a structured engineering approach to ensure system reliability, accuracy, and efficiency. This research utilises a combination of research and development (R&D) frameworks, hardware integration, software programming, and rigorous testing protocols to address the environmental challenges of poultry farming.

### 3.1 Research and Development Frameworks

The development of the system is guided by established systematic models to minimise errors and ensure stability. One primary approach is the waterfall development model, which involves a linear, step-by-step progression through several stages: literature study, observation, data collection, system design, implementation, and evaluation. In the literature stage, theories regarding smart farming, IoT, and poultry physiology are analysed to understand sensor principles and automation logic. Observation involves assessing real coop conditions, such as existing manual temperature regulation and feeding patterns, to define ideal threshold ranges [18].

### 3.2 Hardware Architecture and Sensing Layer

The hardware layer serves as the physical interface between the system and the coop environment. It consists of sensors for data acquisition, microcontrollers for processing, and actuators for environmental control. Figure 3 illustrates the block diagram of the proposed system architecture.

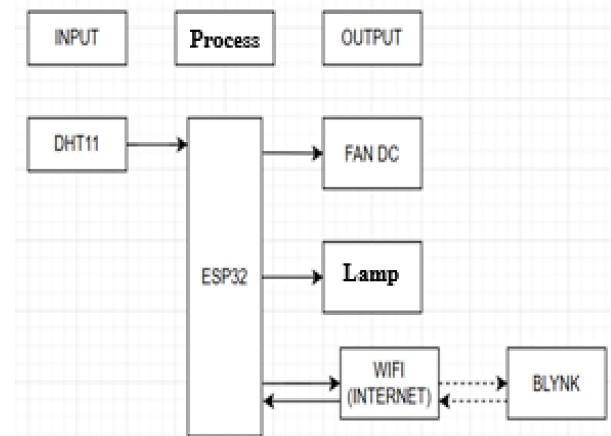


Figure 3: Block diagram

- **Microcontrollers:** The central processing unit of the system is typically a high-performance microcontroller with integrated connectivity. The NodeMCU ESP32 is widely preferred due to its dual-core 32-bit processor, 240 MHz clock speed, and built-in WiFi and Bluetooth capabilities, making it ideal for low-power IoT tasks. Some systems utilise the Arduino Uno R4 WiFi, which incorporates the Renesas RA4M1 processor and integrated ESP32-S3 for wireless networking. For more compact or specialised applications, the Wemos D1 Mini (based on ESP8266) or Arduino Mega 2560 paired with an Ethernet Shield is employed.
- **Sensors:** To monitor the microclimate, DHT22 or DHT11 sensors are used to measure temperature and relative

humidity. The DHT22 is often selected for its higher accuracy and wider measurement range compared to the DHT11. Gas monitoring is conducted using the MQ-135 or MQ-7 sensors, which detect hazardous concentrations of ammonia ( $\text{NH}_3$ ) and other gases by measuring changes in electrical resistance when exposed to these substances. Light intensity is measured using TEMA6000 ambient light sensors or LDRs, while ultrasonic sensors and load cells (via HX711 modules) are used to monitor feed availability and livestock weight, respectively.

- **Actuators:** Control is executed through relay modules, which act as electromagnetic switches to manage high-voltage devices. These relays trigger exhaust fans for cooling and ventilation, incandescent heating lamps for warmth, and water pumps or servo motors for feed and water distribution [19].

Figure 4 shows the flowchart of the ESP32-based temperature and humidity monitoring and control system integrated with the DHT11 sensor and blynk platform.

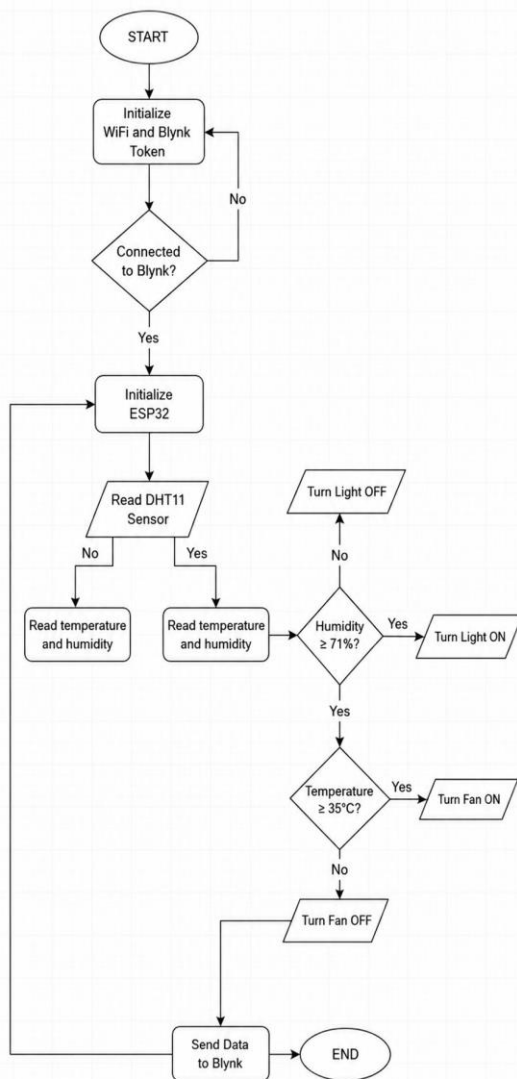


Figure 4: Flowchart of ESP32-based temperature and humidity monitoring system using blynk

### 3.3 Software Development and Logic Design

The software layer defines the intelligence of the system. Programming is primarily conducted using the Arduino IDE using C/C++.

- **Automatic Control Logic:** The system employs various algorithms to manage the environment. The most common is Thresholding, where specific actions are triggered based on predefined limits (e.g., activating a heater if  $T < 28^\circ\text{C}$  or a fan if  $T > 34^\circ\text{C}$ ). More advanced systems implement Fuzzy Logic (Tsukamoto method), which uses linguistic variables (e.g., "cold," "normal," "hot") and inference rules to provide smoother actuator responses and handle environmental uncertainty. Some research even applies Gaussian Naive Bayes, a machine learning classification algorithm that categorizes the coop environment as "ideal" or "bad" based on sensor probability distributions, achieving high predictive accuracy.
- **Telemetry and User Interface:** Data is transmitted to users through various IoT platforms. Blynk is frequently used for mobile monitoring, providing an intuitive dashboard with real-time gauges and manual override switches. Telegram Bots are integrated to send instant alarm notifications regarding high ammonia or extreme temperatures. For comprehensive data logging, custom web dashboards are built using PHP, Laravel, MySQL, and Bootstrap, allowing farmers to view historical trends and analytical reports.

### 3.4 Connectivity and Data Transmission

System connectivity relies on WiFi using standard protocols. Many systems use HTTP with HttpClient for direct web server communication. More robust implementations utilize the MQTT (Message Queuing Telemetry Transport) protocol, which follows a Publish/Subscribe model through an MQTT Broker to ensure rapid, low-latency data exchange between sensors and dashboards. In industrial-grade setups, Modbus TCP/IP communication is established between PLC Siemens S7-1200 units and HMI Droid interfaces to maintain precise synchronization between local and remote monitoring [20].

### 3.5 Testing and Evaluation Procedures

The effectiveness of the system is evaluated through rigorous testing phases:

- **Simulation Testing:** Tools like Cisco Packet Tracer are used to model the network logical flow and simulate sensor-actuator interactions before physical construction.
- **Functional (Black-Box) Testing:** This ensures that every hardware component, from the DHT22 readings to the relay triggers, functions according to the design specifications.
- **Accuracy and Calibration:** Sensor readings are compared against industrial-standard measuring tools (e.g., thermometers and hygrometers). The margin of error is calculated, and correction factors are applied in the software to ensure high precision.
- **Performance Metrics:** The system's effectiveness is measured by its response time (averaging around 4.12 seconds for remote commands), environmental stability (maintaining ideal temperature and ammonia levels), and energy efficiency.

- **Classification Validation:** For systems using machine learning, a Confusion Matrix is applied to training and test datasets to calculate Accuracy. Therefore, in Figure 5 illustrates the program testing and evaluation procedures.

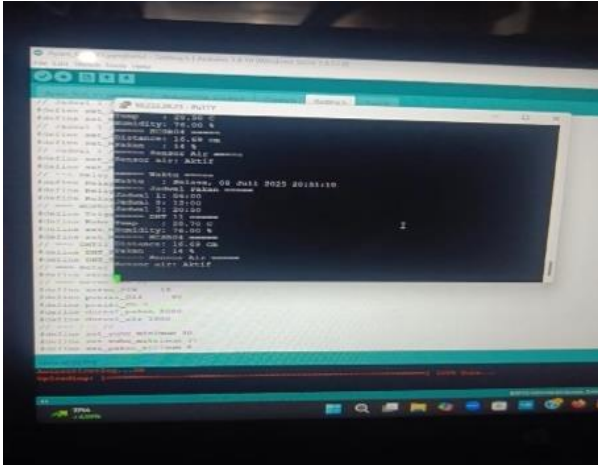


Figure 5: Program testing and evaluation procedures

By integrating these diverse methodologies, the system provides a comprehensive, scalable, and highly effective solution for modernizing poultry coop management through IoT telemetry and automation.

#### 4. RESULT AND DISCUSSION

The implementation of the Internet of Things (IoT)-based telemetry monitoring and automatic control system has yielded comprehensive data regarding its effectiveness in managing poultry coop environments. This section provides an in-depth analysis of the system's functional performance, sensor accuracy, control logic efficiency, and the resulting impact on energy consumption and livestock health. Figure 6 depicted the system wiring configuration.

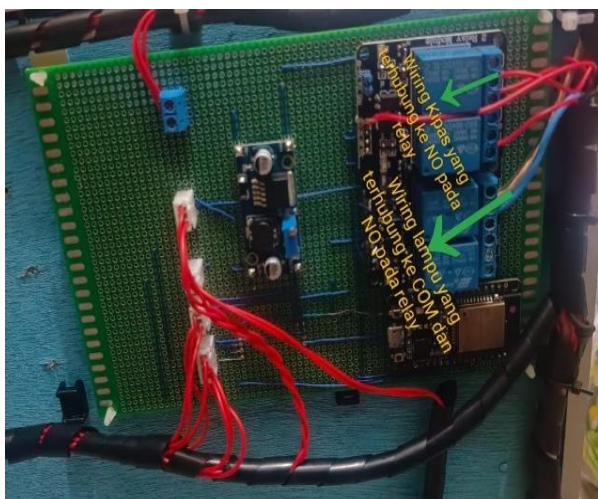


Figure 6: Wiring system

#### 4.1 System Implementation and Functional Performance

The research successfully integrated hardware components, including NodeMCU ESP32, Wemos D1 Mini, and Arduino Uno R4 WiFi, with various environmental sensors and actuators. The physical implementation across multiple studies confirms that these microcontrollers are capable of handling simultaneous data acquisition from DHT22 (temperature/humidity), MQ-135 (ammonia), and Load Cells (weight) while maintaining a stable connection to the internet via WiFi.

Functional testing using Black-Box methodologies demonstrated that the system consistently met its design specifications. For instance, in the Wemos D1 Mini configuration, the system successfully executed commands sent via Telegram Bot inline keyboards with a high degree of reliability. In simulations conducted using Cisco Packet Tracer, the logical flow between the home gateway and mobile devices was verified, ensuring that remote telemetry and manual overrides functioned without network logic failures [21].

#### 4.2 Sensor Accuracy and Data Reliability

A critical metric for the effectiveness of a telemetry system is the accuracy of its data. Comparative analyses between the digital sensors used in the IoT systems and industrial-standard measuring tools revealed negligible margins of error.

- **Temperature and Humidity Accuracy:** The DHT22 and BME280 sensors showed high precision. In a study conducted at Universitas Hasanuddin, sensor readings were compared against an Automatic Weather System (AWS). The results showed a temperature difference of only 0.3°C to 0.8°C and a humidity difference of 1% to 5%. These errors fall well within the acceptable tolerance for poultry farming, where fluctuations of  $\pm 1^\circ\text{C}$  do not significantly impact bird physiology.
- **Ammonia Detection:** The MQ-135 sensor effectively monitored hazardous gas levels. Testing involved exposing the sensor to ammonia solutions and smoke sources (e.g., mosquito coils), where the system successfully recorded fluctuations ranging from a baseline of 17 ppm to a peak of 153 ppm. While the MQ-135 requires careful calibration, it proved capable of detecting levels exceeding the safe threshold of 20 ppm, triggering necessary ventilation responses. Figure 7 shows ammonia graph. Table 1 displays the comprehensive results of the ammonia concentration tests. This data is essential for analyzing chemical changes and environmental impacts during the experiment.

Table 1: Ammonia testing

Time	Ammonia Value	Information
01.00	17	Normal
02.00	19	Normal
03.00	24	Disturbing
04.00	52	Disturbing
05.00	80	Dangerous
06.00	126	Very Dangerous
07.00	68	Dangerous
08.00	70	Dangerous

Time	Ammonia Value	Information
09.00	128	Very Dangerous
10.00	22	Normal
11.00	95	Dangerous
12.00	150	Extreme Dangerous
13.00	39	Disturbing
14.00	107	Very Dangerous
15.00	48	Disturbing
16.00	32	Disturbing
17.00	18	Normal
18.00	33	Disturbing
19.00	28	Disturbing
20.00	18	Normal

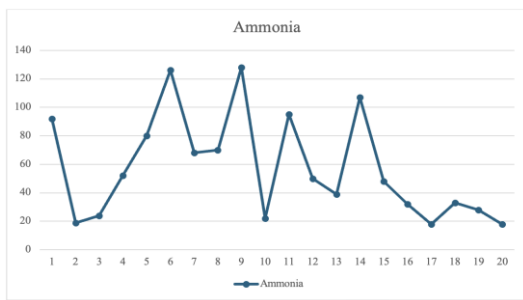


Figure 7: Ammonia graph

- Weight Monitoring:** Systems utilizing Load Cells and HX711 modules provided real-time tracking of chicken growth. When compared to digital factory scales, the IoT system showed a minimal difference of only 2 grams (e.g., 113g vs 115g on day 8), confirming its reliability for monitoring productivity trends.

#### 4.3 Effectiveness of Automatic Control Logics

The intelligence of the system was evaluated using three primary control algorithms: Thresholding, Fuzzy Tsukamoto, and Gaussian Naive Bayes. These algorithms were applied to analyze and optimize the system's decision-making performance.

Illustrated in the Figure 8 is an IoT-based monitoring system that captures live environmental parameters, including temperature, humidity, light intensity, and MQ7 sensor data. The platform also integrates status toggles for the heater and lamp, paired with historical data trends to facilitate continuous environmental management. The dashboard shows a temperature value of 17.2°C, humidity of 53.3%, light intensity of 62.3 lux, and MQ7 gas sensor reading of 208.8 CO, indicating that the environmental parameters are being monitored in real time through the IoT system. Furthermore, the heater status is active (ON) while the lamp status is inactive (OFF), and the sensor statistics graph illustrates fluctuations in temperature, humidity, and light intensity values over a continuous monitoring period.

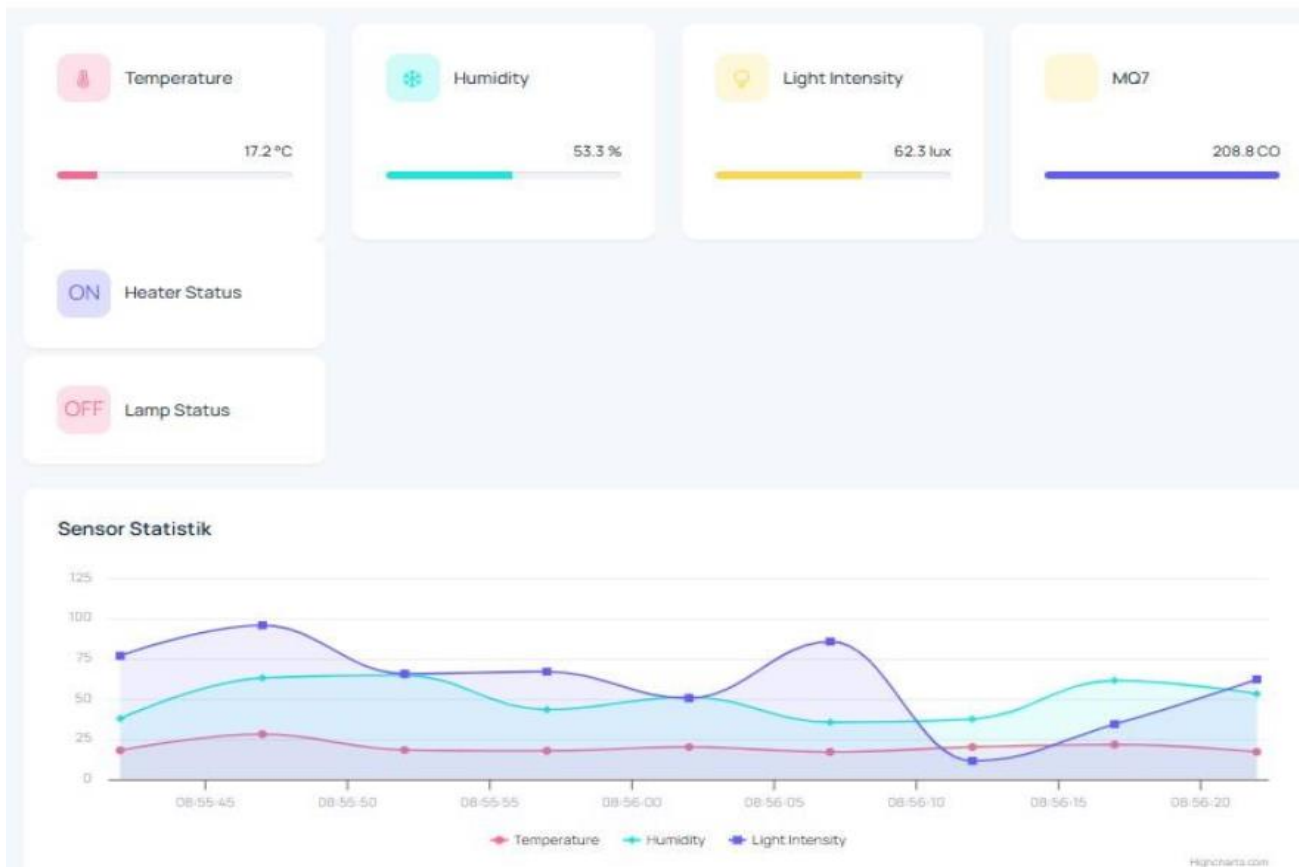


Figure 8: Sensor statistic

### 4.3.1 Thresholding Logic

This method proved to be the most straightforward and reliable for basic automation. By setting specific limits, such as turning on the heaters at  $T < 28^{\circ}\text{C}$  and exhaust fans at  $T > 34^{\circ}\text{C}$ , the system maintained the coop within an ideal range. To optimize efficiency, environmental parameters were continuously sampled and evaluated at 10-minute intervals. This specific temporal resolution proved sufficient for mitigating sudden microclimatic fluctuations while maintaining system stability. Furthermore, by preventing rapid, repetitive cycling of the equipment, this interval successfully minimized mechanical wear on the actuators and prevented unnecessary energy consumption.

### 4.3.2 Fuzzy Tsukamoto Logic

Advanced implementations used fuzzy logic to handle environmental uncertainty. Instead of a simple ON/OFF response, this logic mapped sensor data into linguistic variables (e.g., "cold", "normal", and "hot"). Testing showed that a fuzzy-based system maintained an average temperature of  $30.5^{\circ}\text{C}$  and ammonia levels at 10.8 ppm over a 48-hour period. The primary advantage of this method is the stability it provides; by calculating a smooth output for the fans and lamps, it reduced sharp environmental spikes that cause stress in broiler chickens.

### 4.3.3 Gaussian Naive Bayes Classification

For systems requiring predictive monitoring, the Gaussian Naive Bayes algorithm achieved a classification accuracy

of 91.87% in identifying "ideal" vs. "bad" coop conditions. With a training set of 573 data points and a test set of 246 points, the algorithm demonstrated high recall (94.74%), meaning it was exceptionally good at identifying dangerous environmental states before they escalated. This precision allows farmers to rely on the system for autonomous decision-making in complex environments.

### 4.4 Telemetry and Remote Connectivity

The effectiveness of the telemetry aspect was measured by response time and accessibility.

- **Response Time:** In systems integrated with Telegram bots, the average latency between a command being issued on a smartphone and the actuator activating in the coop was recorded at 4.12 seconds. This rapid response is vital during sudden heatwaves or equipment failures where every minute counts for livestock survival [22].
- **Visualisation and Logging:** Platforms like Blynk and custom Laravel web dashboards provided intuitive interfaces for farmers. The integration of MQTT protocols ensured real-time data streaming to the dashboards without significant delay. Historical data logging allowed for trend analysis, helping farmers correlate growth rates with environmental conditions over the entire 35-day harvest cycle.

broiler-guard-main.data\_sensors: 216 rows total (approximately)    >> Next    Show all    Sorting    Col

id	device_id	temperature	humidity	light_intensity	MQ7	created_at	updated_at
1	A001	19,8	42,2	36,9	713,5	2024-06-19 05:40:36	2024-06-19 05:40:36
2	A001	29,9	60,1	61,4	952,9	2024-06-19 05:40:37	2024-06-19 05:40:37
3	A001	24,5	35,3	39,9	92,2	2024-06-19 05:40:48	2024-06-19 05:40:48
4	A001	29,5	69,9	48,7	480,0	2024-06-19 05:40:53	2024-06-19 05:40:53
5	A001	24,2	54,9	78,0	85,0	2024-06-19 05:40:58	2024-06-19 05:40:58
6	A001	26,5	43,8	94,7	693,2	2024-06-19 05:41:03	2024-06-19 05:41:03
7	A001	18,2	52,4	37,1	1.184,4	2024-06-19 05:41:08	2024-06-19 05:41:08
8	A001	26,8	52,0	46,4	915,3	2024-06-19 05:41:13	2024-06-19 05:41:13
9	A001	26,0	30,7	34,9	1.069,3	2024-06-19 05:41:18	2024-06-19 05:41:18
10	A001	19,6	48,1	78,2	771,7	2024-06-19 05:41:23	2024-06-19 05:41:23
11	A001	22,4	58,9	54,7	993,1	2024-06-19 05:41:28	2024-06-19 05:41:28
12	A001	18,2	41,1	86,6	419,7	2024-06-19 05:41:33	2024-06-19 05:41:33
13	A001	28,9	49,7	9,9	781,4	2024-06-19 05:41:38	2024-06-19 05:41:38
14	A001	21,7	31,9	41,6	235,1	2024-06-19 05:41:43	2024-06-19 05:41:43
15	A001	24,9	55,6	84,8	615,5	2024-06-19 05:41:48	2024-06-19 05:41:48
16	A001	22,2	45,3	5,8	885,9	2024-06-19 05:41:53	2024-06-19 05:41:53
17	A001	28,0	47,5	55,6	400,3	2024-06-19 05:41:58	2024-06-19 05:41:58
18	A001	22,9	55,6	67,0	157,9	2024-06-19 05:42:03	2024-06-19 05:42:03
19	A001	21,0	33,4	35,5	790,5	2024-06-19 05:42:08	2024-06-19 05:42:08
20	A001	26,9	68,1	69,8	426,3	2024-06-19 05:42:13	2024-06-19 05:42:13
21	A001	16,4	69,3	76,2	909,0	2024-06-19 05:42:18	2024-06-19 05:42:18
22	A001	26,3	44,2	47,0	959,9	2024-06-19 05:42:23	2024-06-19 05:42:23
23	A001	24,2	37,0	57,0	1.127,1	2024-06-19 05:42:28	2024-06-19 05:42:28

Figure 9: Real time data

### 4.5 Energy Efficiency and Economic Impact

One of the most significant findings was the impact of automation on resource management. Manual monitoring often results were in fans or heaters being left on for longer than necessary due to the lack of real-time data. In contrast, the IoT-based thresholding system only activated these high-power devices when the environment deviated from the ideal range.

Data measured over three consecutive days revealed a 25% reduction in electricity consumption. Specifically, average daily energy usage dropped from 200 Wh (manual) to 150 Wh (automatic). For large-scale farms with dozens of fans and industrial heaters, this percentage represents a substantial decrease in operational costs and an increase in net profit.

#### 4.6 Impact on Livestock Health and Productivity

The ultimate goal of the telemetry system is to enhance livestock welfare. By maintaining constant environmental stability, the systems directly contributed to improved biological outcomes:

- **Mortality Reduction:** Maintaining ammonia below 20 ppm and temperatures within the 28°C-34°C range prevented respiratory infections and heat stress-related deaths.
- **Growth Optimisation:** Automated feeding and stable temperatures ensured that chickens converted feed into meat more efficiently. In traditional coops, birds often divert energy to maintaining body heat if it is too cold or reduce intake if it is too hot. The IoT system mitigated these issues, allowing birds to reach harvest weight (approx. 1.8 kg) more consistently.
- **Ammonia Management:** High ammonia levels (peaking at 153 ppm in some tests) were quickly mitigated by the automated exhaust fans triggering at a threshold of 1.0 ppm in smart configurations, preventing the eye irritation and immune suppression associated with gas buildup.

#### 4.7 Discussion: Challenges and Future Outlook

While the system is highly effective, the discussion of the results must also acknowledge operational challenges. Most of the hardware used, such as ESP32 and DHT11/22, is sensitive to the harsh conditions of a poultry coop, which is often dusty and humid. Over time, sensor accuracy can drift without regular cleaning and recalibration.

Furthermore, while the WiFi connectivity was stable in laboratory and village settings, large industrial farms may face signal interference from the metal structures of the coops. Future developments should consider the use of LoRa (long range) technology for better signal penetration and lower power consumption in remote areas. Additionally, the integration of artificial intelligence (AI) for predictive disease modelling, as suggested by the high accuracy of the Naive Bayes model, could transition the system from a reactive controller to a proactive farm management ecosystem [23].

#### 4.8 Summary of Results

The synthesised data from various research implementations proves that:

- IoT-based systems are technically feasible and functionally robust for poultry automation.
- Telemetry significantly improves the response speed to environmental threats.
- Advanced Logic (Fuzzy/Machine Learning) provides a more stable microclimate than simple manual methods.
- Economic benefits are realised through a 25% energy saving and reduced labour requirements.

In conclusion, the transition from conventional to IoT-based telemetry and control systems is not only effective but also essential for the modernisation of the poultry industry, ensuring high meat quality and optimal operational efficiency.

## 5. CONCLUSION

The comprehensive evaluation of Internet of Things (IoT)-based telemetry monitoring and automatic control systems for poultry environments demonstrates a profound shift in the

management of broiler chicken coops, transitioning from inefficient manual practices to high-precision autonomous frameworks. This research confirms that the integration of microcontrollers, advanced sensors, and remote communication protocols effectively addresses the critical environmental challenges that have historically hampered productivity and livestock welfare in the poultry sector.

The primary finding of this study is that IoT-based systems are technically robust and functionally reliable for maintaining the delicate microclimate required for broiler growth. Traditional monitoring methods, which depend heavily on human presence and periodic physical inspections, often fail to detect sudden environmental fluctuations—such as sharp temperature spikes or rapid ammonia buildup—until significant damage or mortality has occurred. In contrast, the systems implemented using Arduino Uno R4 WiFi, NodeMCU ESP32, and Wemos D1 Mini provide continuous, 24/7 data acquisition, ensuring that no deviation from ideal conditions goes unnoticed.

The effectiveness of these systems is grounded in the accuracy of the sensing layer. The use of DHT22 and BME280 sensors consistently provided high-precision measurements of temperature and humidity, with error margins often below 1°C for temperature and 5% for humidity when compared to industrial standards. Furthermore, the implementation of MQ-135 gas sensors successfully addressed the "silent threat" of ammonia, allowing the system to trigger ventilation long before concentrations reached toxic levels of 20 ppm, which can cause respiratory failure and immune suppression in birds.

A significant contributor to the effectiveness of these systems is the application of autonomous control logic. The research highlights a progression from simple thresholding to more sophisticated algorithms like fuzzy Tsukamoto and Gaussian Naive Bayes.

- Thresholding logic proved to be a practical and efficient baseline, maintaining coop temperatures within the optimal range of 28°C–34°C by automatically switching on fans or heaters.
- Fuzzy Tsukamoto offered superior environmental stability by handling the uncertainty of sensor data and providing a "smooth" response from actuators, which prevented the sharp climate fluctuations that cause physiological stress in young chicks.
- Gaussian Naive Bayes demonstrated the potential for machine learning in poultry management, achieving a classification accuracy of 91.87% in predicting "ideal" versus "bad" environment states. This level of precision allows for proactive management, identifying dangerous trends before they impact livestock health.

Beyond biological outcomes, the adoption of IoT telemetry yields substantial economic benefits. One of the most quantifiable metrics is the reduction in electricity consumption, which dropped by approximately 25% following the transition to automatic control. This saving occurs because actuators are only powered when environmental conditions cross defined limits, eliminating the energy waste typical of manual systems where fans or lamps are frequently left running unnecessarily.

Furthermore, the reduction in mortality rates and the optimisation of Feed Conversion Ratios (FCR) directly enhance the farmer's profit margins. By preventing heat stress

and respiratory irritation, the system ensures that chickens allocate energy toward meat production rather than biological survival, resulting in more consistent harvest weights and higher-quality meat products.

The telemetry aspect of the system addresses the logistical challenges faced by small to medium-scale farmers, many of whom have other occupations that prevent constant on-site supervision. The integration of Telegram bots, Blynk platforms, and custom web dashboards ensures that critical information is always accessible via smartphone.

- Testing of Telegram-integrated notifications revealed a highly responsive system, with an average response time of 4.12 seconds between a command and an actuator action.
- This remote capability provides farmers with "peace of mind", allowing them to monitor health trends, check feed levels via ultrasonic sensors, and receive emergency alerts for high ammonia or power failures regardless of their location.

Despite the clear effectiveness of IoT solutions, this study identifies several operational challenges. The hardware used, particularly sensors like the DHT11/22 and MQ-135, is sensitive to the harsh, dusty, and humid conditions of a real chicken coop. Frequent calibration and physical cleaning are necessary to prevent sensor drift and maintain accuracy over long-term operation. Furthermore, while WiFi connectivity was successful in the research prototypes, large-scale industrial farms with metallic structures may require the adoption of LoRa (long range) technology for better signal penetration and lower power consumption.

The findings of this research support the global shift toward Industrie 4.0 and Agriculture 4.0, where data-driven decision-making replaces traditional intuition. By creating a closed-loop system where the environment can self-regulate, the poultry industry can achieve a level of scalability previously impossible for manual farmers. This technology democratizes precision farming, making industrial-grade climate control affordable and accessible for smallholder farmers in developing regions.

For the next stage of development, the integration of artificial intelligence (AI) for predictive analytics is highly recommended. Future systems should move beyond reactive responses to proactive forecasting, using historical data to predict disease outbreaks or seasonal climate changes. Additionally, the incorporation of automated waste cleaning systems (e.g., conveyor belts) would further improve air quality by removing the source of ammonia at the onset of buildup.

In conclusion, the IoT-based telemetry monitoring and automatic control system is an exceptionally effective solution for modernising poultry coop management. It replaces high-risk manual labour with a stable, high-accuracy framework that improves environmental stability, reduces operational costs by 25%, and enhances livestock productivity. While technical hurdles regarding hardware durability remain, the functional success of these systems establishes them as an essential technology for the sustainable and profitable future of the poultry industry. The transition from conventional farming to smart farming is no longer just a technological option but a necessary evolution for food security and animal welfare.

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