

*Internet of Things*

Internet of Things Based System for Detecting Egg Theft Attempts in Quail Layer Housing

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A B S T R A C T

The increasing number of quail egg farmers in West Sumatra has raised the demand for more effective security systems. Conventional security methods such as padlocks and latches often fail to prevent egg theft, especially due to the cage's distance from the farmer's residence. This research proposes an Internet of Things (IoT)-based egg theft detection system using fuzzy logic. The system consists of three modules: Module 1 for motion detection and threat level processing using fuzzy logic algorithm, Module 2 as an egg weighing platform to detect weight changes, and Module 3 for sending Telegram notifications and triggering alarms. Modules communicate using ESP-NOW and LoRa SX1278 protocols. Fuzzy logic is employed to determine the threat level based on weight change and motion detection data. Testing results show that the system successfully detects theft attempts in real time, sends alerts via Telegram bot, and activates alarms according to the threat level. The system improves the efficiency and effectiveness of quail cage house security.

INTRODUCTION

Quail farming is a growing sector in Indonesia, offering an alternative to conventional poultry due to its low investment requirements, efficient land usage, and relatively high productivity. In West Sumatra, quail farming has shown significant development. According to the Department of Livestock and Animal Health of West Sumatra Province, the quail population in Lima Puluh Kota Regency reached over 615,000 in 2023, with egg production exceeding 1.1 million kilograms in 2022. This growth reflects increasing interest and participation in the industry [2][3].

Despite the potential economic value, security in quail egg farming remains a neglected aspect, especially among small-scale farmers. Many continue to rely on traditional locks and latches to secure their egg storage. Eggs are often left in the cages after harvesting due to operational convenience, which increases vulnerability to theft particularly when the cages house are located far from the farmer's residence. Several incidents of egg theft have been reported, often occurring at night and resulting in financial losses. The lack of real-time monitoring or alerts leaves farmers unaware until the damage is done.

Recent technological advances, particularly in Internet of Things (IoT), have enabled new possibilities for smart farming. Various studies have explored IoT applications in poultry egg farming, including automatic feeding, environmental monitoring, and basic motion detection. However, many of these solutions focus on general livestock management and do not address the specific issue of theft. Furthermore, existing systems tend to rely on internet connectivity and are not optimized for rural conditions where Wi-Fi access may be limited [4][5].

This situation highlights a gap in current solutions a need for an affordable, real-time, and offline-capable system that can assist farmers in monitoring and securing their quail egg production. Such a system must be tailored to the realities faced by small-scale farmers in rural areas, where infrastructure is often limited, and operational budgets are constrained. In these contexts, the technology deployed should be low-cost, energy-efficient, and simple to install and maintain, without requiring continuous internet access or complex configurations. Moreover, effective security monitoring should not rely solely on single-sensor detection or basic triggers; instead, it should incorporate intelligent decision-making capabilities to evaluate events based on multiple parameters, such as movement patterns and physical changes in weight. This would allow for a more accurate assessment of potential threats and reduce false alarms that could

lead to user fatigue or system neglect. Addressing these challenges requires a context-aware monitoring solution that is adaptive, robust, and practical for rural farming environments. This study aims to contribute to this field by exploring a feasible security approach tailored to the operational conditions and limitations faced by small-scale quail farmers.

METHOD

This research implements an engineering-based method to design a theft detection system for quail egg farming using Internet of Things (IoT) technology, a load cell array, motion sensor, and fuzzy logic. The system is divided into three wireless modules operating independently. The weight sensing module (Module 2) uses four 50 kg load cells arranged in a Wheatstone bridge configuration beneath the egg tray platform. These sensors detect any reduction in egg weight and send the data to the monitoring module (Module 1) via ESP-NOW communication. Simultaneously, Module 1 uses a PIR sensor to detect motion near the cage. Both the weight change and motion data are processed in real time by an ESP32 microcontroller using a fuzzy logic algorithm to determine the threat level. The resulting classification—none, medium, or high—is transmitted to the alarm module (Module 3) using LoRa communication. If a medium threat is detected, a warning is sent via Telegram; if the threat is high, a buzzer is activated alongside an urgent notification, allowing the farmer to respond immediately without relying on constant internet connectivity at the cage location.

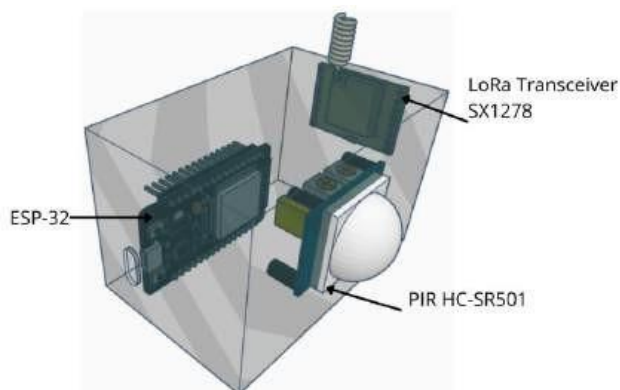


Figure 1 Module 1

Figure 1 illustrates the design of Module 1, which acts as the monitoring and decision-making unit in the quail cage security system. This module is built using an ESP32 DOIT DevKit V1 microcontroller and integrates two key components: a PIR sensor (HC-SR501) and a LoRa SX1278 module. The PIR sensor detects movement in the cage area, while the ESP32 also receives input from Module 2 (weight change data) via ESP-NOW. These inputs are processed using a fuzzy logic algorithm to determine the threat level. Depending on the threat level, the module transmits the classification to Module 3 through the LoRa network. The design prioritizes real-time decision-making without relying on cloud processing, enabling effective offline operation.

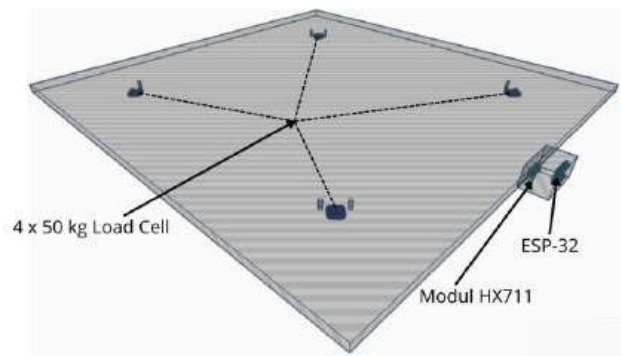


Figure 2 Module 2

Figure 2 shows the configuration of Module 2, which serves as the weight sensing platform placed beneath the quail egg tray. The module consists of four 50 kg load cells positioned at the corners of a 90 cm × 90 cm wooden platform. These load cells are connected in a Wheatstone bridge arrangement to an HX711 module, which amplifies and converts the analog signal into digital form. An ESP32 microcontroller collects the digital weight data and calculates the difference from a set point defined at the time of egg collection. If a significant weight reduction is detected, it is sent to Module 1 via ESP-NOW. This module operates continuously during the monitoring phase and is powered by a direct DC supply to ensure system stability.

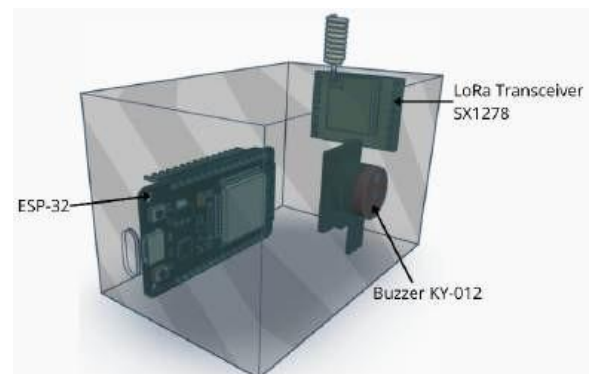


Figure 3 Module 3

Figure 3 presents the layout of Module 3, which functions as the alert and notification system located in the farmer's residence. It features an ESP32 microcontroller, a KY-012 buzzer, and a LoRa SX1278 module. Upon receiving the threat level from Module 1 via LoRa, the ESP32 triggers appropriate actions. For medium threats, it sends a Telegram message to the farmer via Wi-Fi. For high threats, it activates the buzzer while simultaneously sending a more urgent Telegram alert. This design allows the farmer to be notified promptly in both moderate and critical situations, enhancing the security of egg storage without requiring the farmer's physical presence at the cage house.

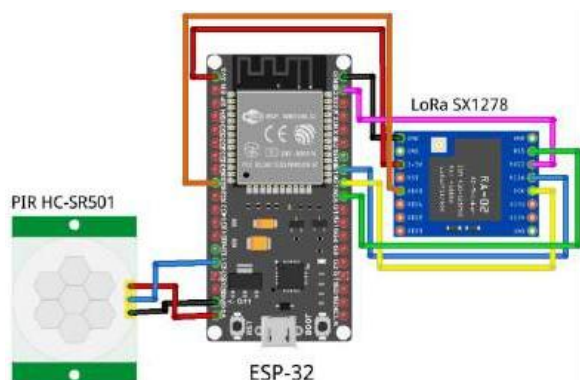


Figure 4 Circuit Schematic of Module 1

Figure 4 shows the circuit schematic for Module 1, which includes an ESP32 DOIT DevKit V1 microcontroller as the microcontroller. The PIR sensor (HC-SR501) is connected to one of the ESP32's digital input pins (GPIO 13) and is powered through the 5V and GND pins. The LoRa SX1278 module is connected via SPI protocol, utilizing the MISO, MOSI, SCK, and CS pins, along with VCC (3.3V) and GND. The module reads binary input from the motion sensor and weight change data from Module 2 via ESP-NOW, processes it with an onboard fuzzy logic algorithm, and transmits the threat level via LoRa.

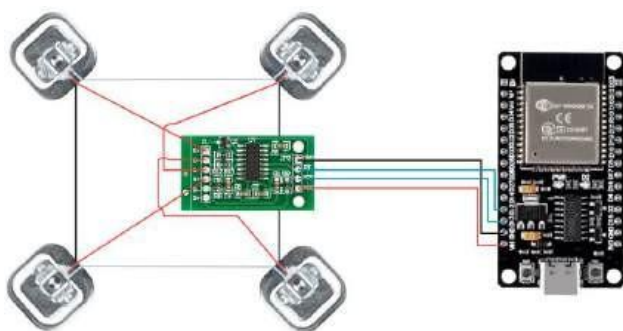


Figure 5 Circuit Schematic of Module 2

Figure 5 shows the schematic circuit of Module 2, which functions as the egg weight detection unit. This module utilizes four 50 kg load cells wired into a full Wheatstone bridge configuration. The analog output from these load cells is routed through the HX711 amplifier module, which is then connected to the ESP32 via its digital pins (DT and SCK). Power is supplied to the HX711 using 5V from the ESP32, and all grounds are connected to a common GND to ensure signal accuracy. The ESP32 reads and processes the digital weight data and transmits any significant changes to Module 1 using ESP-NOW protocol.

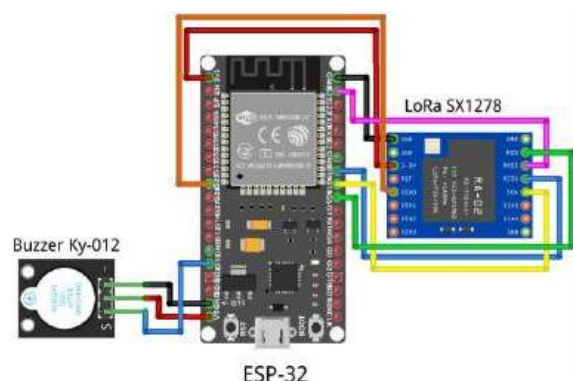


Figure 6 Circuit Schematic of Module 3

Figure 6 presents the schematic circuit of Module 3, the alert and notification module located in the farmer's home. The core of the module is the ESP32, which is connected to the LoRa SX1278 module for receiving messages from Module 1. The LoRa module is connected via SPI interface with proper voltage referencing (3.3V VCC and GND). The KY-012 active buzzer is connected to one of the ESP32's digital output pins (GPIO 13) and powered via the 5V line, with its GND connected to the ESP32's ground. The ESP32 also uses its Wi-Fi capability to send notifications to the farmer via Telegram bot.



Figure 7 General System Flowchart

Figure 7 illustrates the general process flow of the system. The process begins with the initialization of all modules. After initialization, Module 2 measures the current egg tray weight and calculates the difference from the previously set baseline (set point). Simultaneously, Module 1 activates its motion sensor to monitor any movement around the egg area. Both weight change data from Module 2 and motion status are received and processed by Module 1. These inputs are then evaluated using a fuzzy logic algorithm to determine the threat level. Based on this inference, the system classifies the situation into one of three categories: no threat, medium threat, or high threat.

If no threat is detected, the system returns to continuous monitoring. If a medium threat is detected, Module 1 sends a "warning" signal to Module 3, which then triggers a Telegram notification. If a high threat is detected, Module 3 activates the buzzer and sends a critical alert to the farmer via Telegram. After executing the appropriate response, the system resets and resumes monitoring, ensuring uninterrupted surveillance.

This system applies fuzzy logic in Module 1 to determine the level of threat based on two input variables: the change in egg weight and the presence of motion. The fuzzification process

converts crisp input values into degrees of membership, allowing the system to make decisions based on gradual changes rather than binary thresholds.

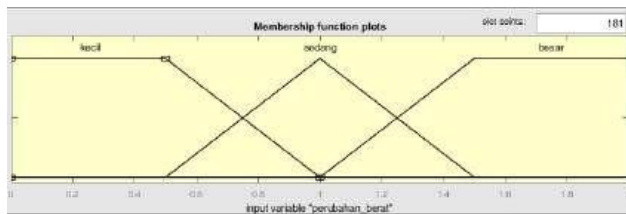


Figure 8 Membership Function for Weight Change

The weight change input is expressed in the range of 0 to 2 kg, with three fuzzy categories used to represent different levels of change in egg mass. A value between 0 to 1 kg indicates a Small change, suggesting normal activity or slight handling. The Medium category spans from 0.5 to 1.5 kg, representing a moderate weight reduction that may indicate potential tampering. The Large category, ranging from 1 to 2 kg, signals a significant loss in egg mass and is considered highly suspicious.

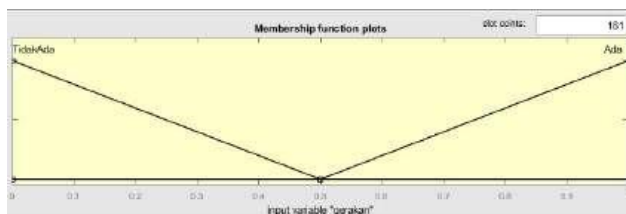


Figure 9 Membership Function for Motion Detection

The motion detection input is derived from a motion sensor and is categorized into two fuzzy sets: No Motion and Motion Detected. This input is binary, with values of 0 indicating No Motion and 1 indicating Motion Detected. Despite its digital nature, this variable is processed within the fuzzy framework to enable integration with other analog-style inputs (such as weight change) and allow nuanced inference based on simultaneous events.

Table 1 Fuzzy Rule

No	Weight Change	Motion Detection	Threat Level
1	Small	None	<i>None (0)</i>
2	Small	Detected	<i>Medium (1)</i>
3	Medium	Detected	<i>High (2)</i>
4	Large	Detected	<i>High (2)</i>

Table 1 presents the fuzzy inference rules that determine the system's output (threat level) based on the combination of two inputs which are weight change and motion detection. The output variable has three possible states which are None, Medium, and High, corresponding to the numerical values 0, 1, and 2.

RESULTS

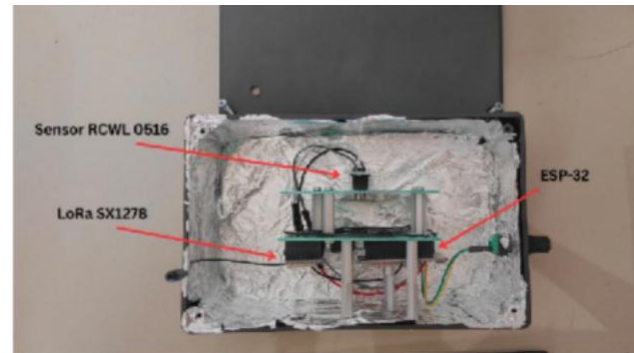


Figure 10 Hardware Implementation of Module 1

The final configuration of Module 1 includes an ESP32 DOIT DevKit V1 microcontroller, a RCWL-0516 microwave motion sensor, and a LoRa SX1278 module, all mounted on a compact prototype board. The system was originally designed using a PIR motion sensor (HC-SR501). However, during physical testing, the sensor was replaced with the RCWL-0516 microwave sensor due to its superior performance in motion detection across a wider range, better sensitivity through thin materials, and less susceptibility to ambient temperature variation. The ESP32 functions as the control unit, receiving motion input from the RCWL-0516 sensor and weight change via ESP-NOW from Module 2. The LoRa SX1278 module is connected via SPI interface and is responsible for sending the evaluated threat level to Module 3. All components are housed in a plastic case and mounted inside the cage house. The sensor is positioned with an unobstructed line of sight to maximize detection of movement near the egg storage area.

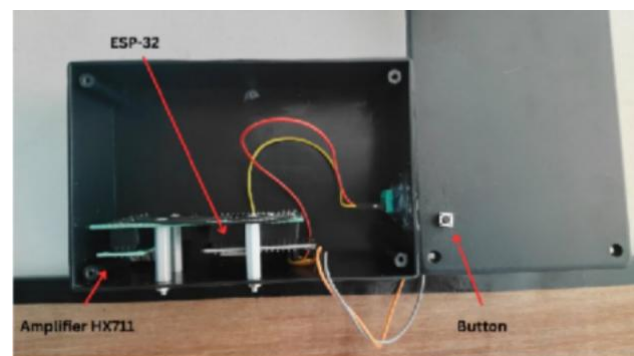


Figure 11 Hardware Implementation of Module 2

Module 2 is implemented as a 90 × 90 cm plywood platform, functioning as a weighing surface for the eggs. At each corner of the underside of the platform, a 50 kg load cell is mounted to support and measure the total weight of collected eggs. The load cells are connected in a full Wheatstone Bridge configuration and interface with an HX711 amplifier module. All electronic components are housed in a protective plastic case that is securely attached to the side of the wooden platform. This enclosure ensures that sensitive electronics are protected from dust, dirt, and environmental hazards while remaining easily accessible for maintenance. Module 2 operates offline and sends weight change data to Module 1 using the ESP-NOW communication protocol after the farmer sets the initial reference weight (set point).

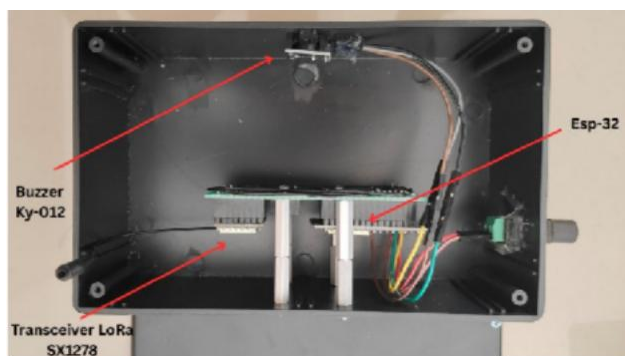


Figure 12 Hardware Implementation of Module 3

Module 3 using an ESP32 DOIT DevKit V1, a LoRa SX1278 module, and a KY-012 active buzzer. The ESP32 is responsible for receiving data from Module 1 and performing two main actions which are sending Telegram notifications and triggering buzzer as alarms. The LoRa module is mounted on the same board and is connected to the ESP32 via SPI. The buzzer is externally mounted on the plastic casing to maximize sound output during high-threat events. The system is powered by a wall adapter, and this module is strategically placed inside the farmer's house, approximately 30–50 meters from the cage, ensuring reliable long-range communication and real-time alerts.

Software Implementation

The software implementation of the quail egg theft detection system is carried out through embedded programming of the three ESP32 microcontrollers that serve as the core of each module. The code is written in C++ using the Arduino IDE. The system operates on an offline local communication framework between Modules 1 and 2 (via ESP-NOW) and a long-range communication between Modules 1 and 3 using LoRa SX1278.

Module 1 receives input data from Module 2 (egg weight changes) and local motion detection via the RCWL-0516 microwave sensor. This data is processed using a Sugeno type fuzzy logic algorithm. Based on this decision, Module 1 sends the threat level to Module 3. Module 3 then acts upon the received threat level. If a medium threat is detected, the system sends a warning notification to the farmer via a Telegram bot. If a high threat is detected, it simultaneously activates a buzzer and sends a danger alert through Telegram.

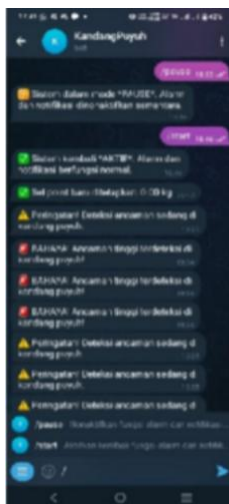


Figure 13 Telegram Notification Output

Figure 14 shows the output of the Telegram bot integrated into the system, which is responsible for sending notifications to the farmer based on the threat level detected. When a medium-level threat is identified, the bot sends a warning message. In the case of a high-level threat, the bot sends a danger alert to notify the farmer of a potential theft attempt. The Telegram bot also supports two manual control commands which are /pause and /start. When the /pause command is sent by the user, the system temporarily disables alert responses, allowing the farmer to safely place or remove eggs on Module 2 without triggering false alarms. Once the /start command is issued, the system resumes normal operation, reactivating threat monitoring and response mechanisms.

Testing and Analysis

RCWL-0516 Sensor Testing

The RCWL-0516 microwave sensor test was conducted to evaluate its ability to detect motion reliably. This sensor operates by emitting microwave signals and detecting motion based on the Doppler effect caused by moving objects within its range. The test focused on a single parameter: the motion state, represented as a digital output of HIGH when motion is detected and LOW when idle. Testing was carried out by positioning a person at varying distances from the sensor, ranging from 1 to 7 meters. Distance measurement was guided by floor tiles, whose dimensions were confirmed using a measuring tape. During the test, the subject performed simple movements at each distance point while the sensor output was monitored via an LED indicator connected to Module 1. The LED would turn on when motion was detected, confirming that the RCWL-0516 was responsive across multiple distance intervals and capable of providing consistent digital output for movement detection in the intended operational environment.

Table 2 RCWL-0516 Motion Sensor Test Results

Test No.	Distance (meters)	Sensor Output	Motion
1	1	HIGH (1)	Detected
2	3	HIGH (1)	Detected
3	4	HIGH (1)	Detected
4	5	HIGH (1)	Detected
5	6	HIGH (1)	Detected
6	6,4	HIGH (1)	Detected
7	7	LOW (0)	Not Detected

Based on the test results presented in Table 2, the RCWL-0516 sensor successfully detected motion at distances ranging from 1 to 6.4 meters, which aligns with the predefined system specifications. In six trials conducted at varying distances, the sensor consistently produced a HIGH output (1), indicating successful motion detection. However, at a distance of 7 meters, the sensor failed to detect movement, producing a LOW output (0), which falls short of the range stated in its datasheet. The testing also revealed key characteristics of the sensor, particularly its ability to detect motion through plastic enclosures, requiring careful adjustment of the detection angle. To optimize directionality, aluminum foil was applied to the inner surfaces of

the sensor's casing to limit the detection angle. Additionally, the module's height placement was adjusted to ensure proper targeting of the detection area. Despite not fully meeting the datasheet's maximum range, the sensor performed reliably within the critical detection range of 3–5 meters, thereby fulfilling the system's operational requirements.

Load Cell Testing

This testing focusing on the four load cell configuration used in Module 2, which plays a key role in detecting changes in egg weight. Two separate tests were conducted. The first evaluates the accuracy of weight measurement by comparing sensor readings with values obtained from a conventional analog scale using various egg weights. The second assesses the system's ability to detect small weight changes, where a 2.10 kg load of quail eggs is gradually reduced to determine whether the system responds to changes in the range of 0.5–1 kg. These tests are essential to confirm that the load cell system can provide reliable input data for further decision making processes.

Table 3 Weight Accuracy Test Result

Test No.	Weight on Analog Scale (Kg)	Weight on Module 2 (Kg)	Difference (Kg)	Accuracy (%)
1	2,20	2,12	0,08	96,4
2	4,30	4,13	0,17	96,0
3	8,50	8,25	0,25	97,1
4	10,70	10,45	0,25	97,7
5	23,00	22,21	0,79	96,6
6	32,70	31,03	1,67	94,9
7	40,70	39,55	1,15	97,2
8	64,70	63,09	1,61	97,5
9	175,00	169,50	5,50	96,9
Average				96,7

Table 4 Weight Change Test Result

Test No.	Current Weight (Kg)	Eggs Taken	Current Egg Count	Weight Change (Kg)
1	2,10	0	200	0
2	2,09	1	199	0,01
3	2,00	10	190	0,10
4	1,81	30	170	0,29
5	1,63	50	150	0,47
6	1,54	60	140	0,56
7	1,04	100	100	1,06
8	0,78	130	70	1,32
9	0,59	150	50	1,51
10	0,29	180	20	1,81

Based on the results in Table 3, the load cell system demonstrates a high level of accuracy in measuring weight, with an average accuracy of 96.7%. Although the deviation slightly increases for heavier loads, the accuracy remains within acceptable limits. This deviation is likely due to the calibration process, which used lighter weights, making the calibration factor less optimal for heavy loads.

As shown in Table 4, the system is also capable of detecting small weight changes with high precision. For example, test 2 recorded a weight change of just 0.01 kg. Repeated tests confirm the system's sensitivity to weight variations in the range of 0.5–1 kg. These results indicate that the weighing module meets system specifications, offering both reliable accuracy and the ability to detect small weight changes.

Ky-012 Buzzer Testing

Testing of the KY-012 buzzer was conducted to evaluate whether the sound output met the system's effectiveness criteria, particularly in noisy environments such as a quail cage. The test involved five trials using an online sound meter (youlean.co) and a laptop microphone. During each trial, the buzzer was positioned near the microphone and activated while ambient noise from the cage was present. The sound level readings were recorded and compared to the system's minimum requirement of 80 dB. This ensured the buzzer's capability to produce sufficiently loud alerts.

Table 5 Ky-012 Buzzer Test Result

Test No.	Sound Intensity (dB)	Standard Compliance
1	90	Meets
2	88	Meets
3	105	Meets
4	85	Meets
5	101	Meets

Based on the test results in Table 5, the KY-012 buzzer successfully produced sound levels exceeding the system's minimum requirement of 80 dB. The measurements ranged between 85 dB and 105 dB, which aligns with the KY-012 datasheet specification stating that the buzzer output is typically ≥ 85 dB. Even when tested in a noisy environment such as the quail cage house, the buzzer's performance remained consistent. These results confirm that the KY-012 buzzer meets the necessary criteria to function as an effective audible alert within the system.

SX1278 LoRa Transceiver Testing

The purpose of the LoRa SX1278 transceiver testing is to evaluate the communication range between the transmitting and receiving modules, simulating the real-world distance from a quail cage to the farmer's residence. In the system, the LoRa module is responsible for transmitting the threat level data from Module 1 to Module 3

The testing was carried out by connecting LoRa modules to two ESP32 boards. One on Module 1 (as transmitter) and one on Module 3 (as receiver). The transmitter was placed at a fixed position, while the receiver was moved to varying distances

between 10 and 50 meters. The environment for testing included common rural obstacles such as stone walls and trees. Distance measurement between modules was conducted using location data from Google Maps coordinates.

Table 6 SX1278 LoRa Transceiver Test Result

Test No.	Distance Between Transceivers (Meter)	LED Status	Data Transmission (Success / Fail)
1	10	ON	Success
2	20	ON	Success
3	30	ON	Success
4	40	ON	Success
5	50	ON	Success
6	55	ON	Success
7	65	ON	Success

Based on the results presented in Table 6, it can be concluded that the LoRa SX1278 modules successfully communicated over the system's required range of 10–50 meters. Even when tested beyond the required range, at distances of 55 and 65 meters, the modules were still able to establish communication. These outcomes confirm that the LoRa modules meet the minimum communication distance requirements for the quail cage monitoring system.

Further analysis reveals specific characteristics of the LoRa communication. At distances between 10–30 meters, signal transmission occurred instantly and reliably. However, at distances of 40–50 meters, the receiving module experienced a slight delay of 10–15 seconds before achieving stable communication. When tested at 55 and 65 meters, communication still occurred but required careful adjustment of the receiver's height and orientation. Once the signal stabilized, the transmission delay was not significantly different from shorter ranges. These behaviors can be attributed to the presence of obstacles such as walls and trees in the testing environment, which likely interfered with initial signal propagation. Overall, the test demonstrates that the LoRa SX1278 transceivers perform reliably and meet the system's communication requirements under typical rural deployment conditions.

Fuzzy Logic Testing

The fuzzy logic algorithm test was conducted to verify whether the system responds correctly according to the six predefined fuzzy rules. The system uses three threat levels (None, Medium, and High) and produces two types of output which are buzzer activation and Telegram notification. The testing procedure involved placing two trays containing a total of 200 quail eggs on top of Module 2, simulating a standard weight load. All modules were then connected, and Module 3 was linked to an internet connection to enable communication with the Telegram bot. Subsequently, several scenarios were tested by varying the weight reduction (classified as small, medium, and large) and combining these with the presence or absence of detected movement. The system's response was then observed to ensure

that each input combination resulted in the correct output action based on the fuzzy logic rules.

Table 7 Fuzzy Logic Test Result

Rule No.	Motion	Weight Change (Kg)	Threat Level	Telegram Notification	Buzzer	Description
1	Not Detected	0,02 (Small)	0	None	Inactive	Match
2	Detected	0,02 (Small)	1	Warning	Inactive	Match
3	Detected	1,10 (Medium)	2	Danger	Active	Match
4	Detected	2,10 (Large)	2	Danger	Active	Match

Based on the results shown in Table 7, the fuzzy logic algorithm successfully produced outputs in accordance with all six predefined rules. When a small weight change occurred without any detected motion, the system produced no output, indicating a threat level of 0 (None). In scenarios corresponding to Rules 2, the system correctly issued a warning notification via Telegram, with a threat level of 1 (Medium) and without activating the buzzer. For Rules 3 and 4, the system correctly triggered a danger alert through the Telegram bot and activated the buzzer, indicating a threat level of 2 (High). These outcomes confirm that the fuzzy logic algorithm operated as intended and was consistent with the design phase. In conclusion, the fuzzy logic implementation met all system requirements and performed reliably in executing threat-level decisions based on sensor input.

Buzzer Activation Delay Testing

Testing was conducted to measure the delay between the weight change on Module 2 and the activation of the buzzer on Module 3. This test evaluates whether the system's response time remains acceptable despite using two communication protocols (ESP-NOW and LoRa). After placing a 2.10 kg load on Module 2 and setting the set point, the load was removed entirely to trigger a high level threat. The time delay until the buzzer activated was measured using a stopwatch, with Module 3 placed at distances of 1, 13, and 20 meters. This helped verify the system's responsiveness across different communication ranges.

Table 8 Buzzer Activation Delay Test Result

Test No.	Distance between Module 1 & 3 (meters)	Total System Delay (seconds)
1	1	2,52
2	1	2,41
3	1	1,98
4	13	1,75
5	13	1,82
6	13	1,99
7	20	2,38
8	20	2,07

9	20	1,91
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Based on the results shown in Table 8, the system recorded a total delay ranging from 1.75 to 2.52 seconds from the moment the weight was removed on Module 2 until the buzzer on Module 3 was activated. This indicates that the system operates with a response time of less than 3 seconds, which is considered efficient for a multi protocol communication setup involving both ESP-NOW and LoRa. Variations in the distance between Module 1 and Module 3, ranging from 1 to 20 meters, did not significantly impact the delay, showing consistent system performance. These results confirm that the buzzer activation delay meets the system's security requirements, ensuring rapid response in potential threat conditions.

System Integration Testing

The system integration test was conducted to evaluate the overall performance when all modules were connected and operated simultaneously. Testing involved simulating various conditions by altering the weight values (small, medium, and large) on Module 2 and combining them with motion detection from the RCWL sensor on Module 1. The results showed that the system consistently responded according to the designed fuzzy logic rules. Level 1 threats (medium) triggered Telegram warning notifications, while Level 2 threats (high) activated both the buzzer and Telegram danger alerts via Module 3. Additionally, the test was carried out at two different distances between Module 1 and Module 3, 1 meter and 10 meters.

Table 9 System Integration Test Result (1 Meter)

Weight Change (Kg)	Motion	Threat Level	Telegram Notification	Notification Delay (s)	Buzzer	Buzzer Delay (s)
0,03 (Small)	Not Detected	0	None	0	Inactive	0
0,03 (Small)	Detected	1	Warning	3,50	Inactive	0
1,13 (Medium)	Detected	2	Danger	2,80	Active	2,52
2,34 (Large)	Detected	2	Danger	2,93	Active	1,98

Table 10 System Integration Test Result (10 Meter)

Weight Change (Kg)	Motion	Threat Level	Telegram Notification	Notification Delay (s)	Buzzer	Buzzer Delay (s)
0,03 (Small)	Not Detected	0	None	0	Inactive	0
0,03 (Small)	Detected	1	Warning	3,13	Inactive	0
1,13 (Medium)	Detected	2	Danger	2,60	Active	1,75

2,34 (Large)	Detected	2	Danger	3,37	Active	1,99
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Based on the test results presented in Tables 9 and 10, the integrated system successfully performed all predefined logic actions across different conditions and distances. At a 1 meter range, the system responded accurately to various input combinations. No output was generated when there was no motion and weight change was small, a warning notification was triggered for medium threat levels, and both buzzer activation and danger notifications were issued for high threat conditions. The system exhibited reliable response times, with buzzer activation delays ranging from 2.32 to 3.03 seconds and Telegram notification delays between 4.85 to 5.90 seconds. Similar tests conducted at a distance of 10 meters confirmed the system's consistency, where outputs matched expected logic, and delay values remained within a comparable range (2.12 to 3.54 seconds for buzzer activation and 4.03 to 5.67 seconds for notification). These results confirm that the fully integrated system is capable of operating reliably at various distances, maintaining accurate threat classification and timely responses essential for effective security monitoring in the quail egg farming environment.

CONCLUSIONS

1. The Internet of Things Based System for Detecting Egg Theft Attempts in Quail Layer Housing was successfully designed according to the proposed concept, both technically and functionally.
2. The RCWL-0516 microwave sensor successfully detects motion within a range of 1 to 6,4 meters, meeting the system's functional requirements.
3. The load cell configuration on Module 2 is capable of detecting weight changes in the range of 0,5–1 kg and can even detect very small changes as low as 0,01 kg.
4. The load cell readings demonstrate high accuracy, consistently above 90%, making them reliable for detecting weight variations.
5. The Ky-012 buzzer effectively generates sound intensities ranging from 85 to 105 dB, ensuring it is audible even in noisy environments.
6. The LoRa SX1278 transceiver can transmit messages reliably over a distance of 10 to 65 meters, even with obstacles such as walls and trees.
7. The implemented fuzzy logic algorithm meets all six predefined rules and produces the correct system outputs for each threat level condition.
8. The system achieves a buzzer activation delay ranging from 2.12 to 3.54 seconds, and Telegram notifications are sent within 4.03 to 5.90 seconds, indicating fast response time suitable for real-time alerting.

RECOMMENDATION

1. The use of full-bridge load cells instead of half-bridge load cells, where full-bridge load cells have internal compensation for temperature and cable resistance, resulting in more stable and accurate measurements.
2. Optimization of system power usage, such as implementing the deep sleep feature on the ESP32, so

that the system can operate more energy-efficiently, especially during standby conditions.

3. Expansion of LoRa communication scalability, where a single LoRa receiver at the farmer's house can receive threat levels from two or more LoRa modules located in different quail houses. This will be useful for farmers who own more than one poultry house.

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