

Design Get up System Cultivation Crickets in a Wireless Clay Barn

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Abstract — Conventional cultivation of field crickets (*Gryllus bimaculatus*) faces challenges in maintaining stable environmental conditions and continuous monitoring. This study developed a Wireless Sensor Network (WSN)-based monitoring and control system using an ESP32 microcontroller integrated with DHT22, LDR, RTC DS3231, and load cell sensors. Temperature and humidity data were processed using the Mamdani Fuzzy Logic algorithm to automatically control heating and misting, while all sensor data were transmitted through Firebase Realtime Database and displayed on a web-based monitoring platform in real time. Experimental results showed that the DHT22 sensor achieved accuracies of 98.97% for temperature and 99.53% for humidity measurements. The LDR sensor successfully classified lighting conditions into dark (5 lux), dim (17 lux), and bright (40 lux). The load cell sensor achieved a Mean Absolute Percentage Error (MAPE) of 0.65% (99.35% accuracy), while the RTC DS3231 maintained accurate time synchronization. The Mamdani Fuzzy Logic algorithm achieved 98.40% accuracy compared with manual calculations. WSN communication performance demonstrated delays of 162.73–171.97 ms, jitter of 60.13–101.51 ms, and throughput of 12.85–14.06 kbps. All sensor data were successfully transmitted and displayed in real time, demonstrating the system's effectiveness for automated, centralized cricket cultivation monitoring and environmental control.

Keywords — Clay Barn, Cricket Cultivation, DHT22, ESP32, Firebase Realtime Database, Internet of Things, Wireless Sensor Network.

I. INTRODUCTION

Crickets are one of the insect commodities that have high economic value and have the potential to support food security and the livestock sector if cultivated optimally. At the global level, insects, including crickets, have been recognized as a sustainable alternative protein source for livestock, poultry, and fisheries feed, while providing economic and health benefits [1]. One of the widely cultivated species is *Gryllus bimaculatus* because it has a high content of protein, chitin, and essential amino acids and good adaptability to the cultivation environment [2], [3]. In fact, research shows that *Gryllus bimaculatus* protein has the potential to stimulate the differentiation of human stem cells into osteoinductive cells, thus opening up opportunities for use in the biomedical field [4].

The success of cricket cultivation is greatly influenced by environmental conditions because these insects are ectothermic animals that depend on the temperature and humidity of their surroundings to carry out metabolic processes, growth, and reproduction [5]. The ideal temperature is in the range of 20–32°C with a relative humidity of 65–80% so that stress levels can be suppressed and nutrient absorption efficiency increases [5]. In addition, lighting also plays an important role in supporting the natural activities of crickets. The recommended light intensity ranges from 30–45 lux with a lighting cycle of 12 hours of light and 12 hours of darkness to adjust to their nocturnal nature so that excessive light exposure can be avoided [6]–[8]. In addition to environmental factors, feed management must also be considered by providing feed and drinking water according

to the maintenance age so that growth takes place optimally [9], [10].

The maintenance media also determines the stability of the cage environment. Clay mushroom houses have a natural ability to maintain temperature and humidity due to their properties as heat insulators, so that temperature fluctuations between day and night can be minimized [11], [12]. However, the use of passive media alone is not able to overcome dynamic changes in environmental conditions, especially in large-scale cultivation. Therefore, the application of automated technology based on the Internet of Things (IoT), artificial intelligence, and Wireless Sensor Network (WSN) is needed to improve the efficiency of cultivation management [1]. IoT allows real-time monitoring of cage conditions through a sensor network, while the Mamdani Fuzzy Logic method is able to produce temperature and humidity control decisions based on logical rules that resemble human decision-making processes [13], [14]. WSN integration also supports data communication between sensor nodes to a central server using the HTTP protocol so that the monitoring process can be carried out centrally and remotely [15], [16].

Conventional cricket farming still relies on the farmer's experience, resulting in incontinent environmental monitoring and subjective control decisions. These conditions have the potential to reduce productivity, increase mortality rates, and reduce time and energy efficiency. Previous research has shown that IoT systems with Fuzzy Logic are capable of controlling temperature and humidity effectively, even achieving an accuracy level of around 90%,

but have not integrated automatic feeding features, sanitation monitoring through weight sensors, and the use of clay barns as a cultivation medium [17]. Based on these conditions, this study developed a WSN-based cricket farming system using ESP32, DHT22 sensors, LDR sensors, load cells, RTC modules, and the Mamdani Fuzzy Logic algorithm. All data is sent to the Firebase Realtime Database so that farmers can monitor and control the cage environment automatically, centrally, and in real-time.

II. METHOD

A. Types of research

The type of research used is research and development (R & D). This research involves the design and construction of an automatic monitoring and control system based on the Internet of Things (IoT) and Wireless Sensor Network (WSN) with the application of the Mamdani Fuzzy Logic method on a clay mushroom media as a place for cricket cultivation. The purpose of this research is to develop an intelligent system that is able to monitor and control environmental parameters in real-time, including temperature, humidity, and light intensity, while also supporting automatic feeding and detection of waste accumulation, in order to create a stable, efficient, and adaptive cultivation environment.

B. Research Stages

The research stages are illustrated in the flowchart shown in Fig. 1. The research began with a literature review, which examined previous studies related to Internet of Things (IoT), Wireless Sensor Networks (WSN), Mamdani Fuzzy Logic, ESP32 microcontrollers, DHT22 sensors, LDR sensors, load cells, Firebase Realtime Database, and web-based monitoring systems. This stage provided the theoretical foundation for designing an automated monitoring and control system for cricket farming.

After the literature review, the system design stage was carried out to determine the overall architecture of the proposed system. This stage included designing the hardware configuration, software architecture, wireless communication mechanism, database structure, and web monitoring interface. The designed system integrates an ESP32 Node Client as the sensor node, an ESP32 Node Master as the gateway, DHT22, LDR, load cell, and RTC DS3231 sensors, Firebase Realtime Database, and a web-based monitoring application into a single IoT ecosystem.

Next, the hardware and materials preparation stage was conducted by preparing all electronic components and supporting equipment required for system development. These components included the ESP32 Node Client, ESP32 Node Master, DHT22 sensor, LDR sensor, load cell with HX711 module, RTC DS3231 module, relay modules, heating lamp, mist maker, servo motor, power supply, and other supporting hardware. At the same time, the required software, including the Arduino IDE, Visual Studio Code, Firebase Realtime Database, and Wireshark, was prepared to

support embedded programming, web development, cloud integration, and Quality of Service (QoS) analysis.

The hardware and software implementation stage involved assembling all hardware components and developing the embedded software for sensor data acquisition, Mamdani Fuzzy Logic processing, actuator control, Wireless Sensor Network communication, cloud data transmission, and web-based monitoring. During this stage, the ESP32 Node Client periodically acquired environmental data, executed the fuzzy inference process, controlled the actuators automatically, and transmitted monitoring data to the ESP32 Node Master before forwarding the information to the Firebase Realtime Database.

Following the implementation stage, sensor calibration was performed to ensure that all sensors produced accurate and reliable measurement results. The DHT22 sensor was calibrated for temperature and humidity measurements, the load cell was calibrated using linear regression, and the LDR sensor was tested under different lighting conditions. If the calibration results did not satisfy the expected accuracy, the system returned to the implementation stage for hardware adjustment or software modification until the required performance was achieved.

After successful calibration, system testing was conducted to verify the functionality and integration of all hardware and software components. The testing covered sensor operation, fuzzy logic execution, automatic actuator control, communication between the ESP32 Node Client and ESP32 Node Master, Firebase data transmission, website monitoring, and Wireless Sensor Network performance. If any functional errors or communication failures were identified during testing, the implementation stage was repeated until all system components operated correctly.

Once the system had successfully passed all testing procedures, data acquisition was carried out by collecting sensor readings, actuator operating durations, and network communication data under actual operating conditions. The collected data were then processed during the data analysis stage to evaluate sensor accuracy, Mamdani Fuzzy Logic performance, Wireless Sensor Network communication quality, and Quality of Service (QoS) parameters, including delay, jitter, throughput, packet loss, and RSSI. Finally, the analysis results were interpreted to determine whether the proposed IoT-based cricket farming monitoring and control system successfully achieved the research objectives of providing automatic, real-time, and reliable environmental monitoring and control.

C. Design

The design phase is carried out to provide a comprehensive overview of the system to be built, both in terms of hardware and software. The design includes the preparation of block diagrams, system flowcharts, network topologies, fuzzy logic design, physical device design, and integration of Firebase-based monitoring systems and websites.

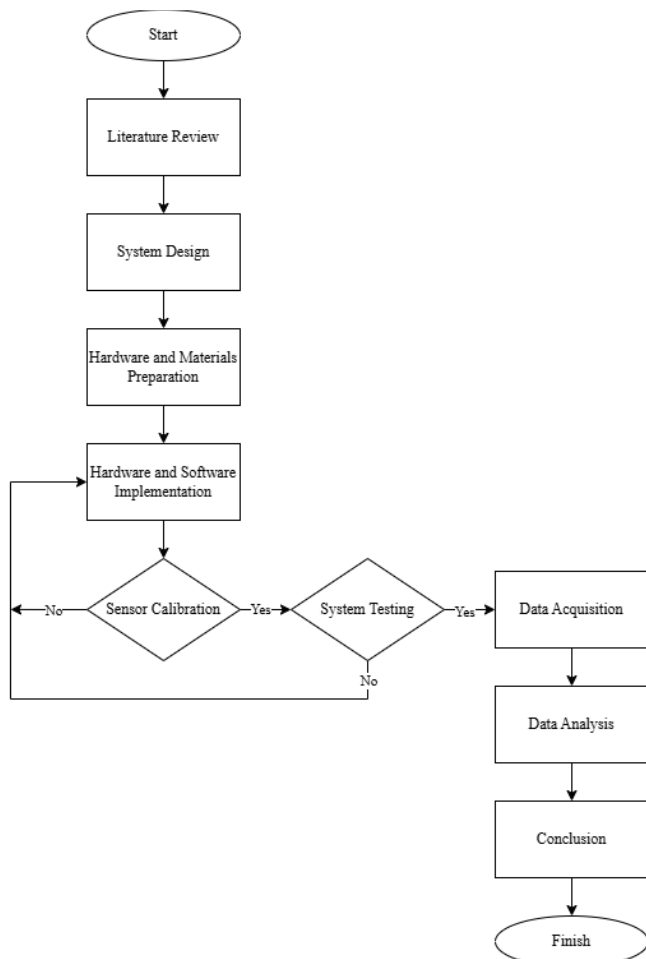


Figure 1. Research flowchart, from problem identification to conclusion

D. Tool Design Planning

The tool design was conducted to provide an overview of the physical form of the *Internet of Things (IoT) -based cricket cultivation system* developed in this research. The tool design took into account the placement of sensors, actuators, and supporting devices to ensure optimal monitoring and control of the greenhouse's environmental conditions. Furthermore, this design also aims to simplify the assembly, installation, and maintenance of the device. The overall implementation of the tool design is shown in Figure 2.

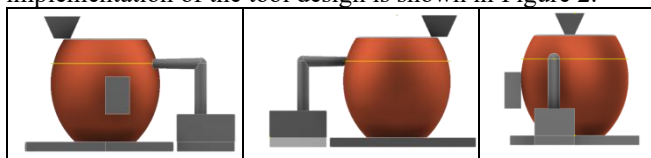


Figure 2. 3D Image of the tool

E. Testing Parameters

The parameters to be tested in this study are as follows:

1. The accuracy level of the DHT22 temperature and humidity sensor in processing the environmental conditions of the clay mushroom house, LDR, and RTC in determining the time of feeding and the load cell in determining the weight of the mushroom house.

2. Testing the accuracy level of the *Mamdani Fuzzy Logic algorithm*.
3. Signal Strength Testing, nodes with servers in *Wireless Sensor Network*.
4. *Quality of Service (QoS)* testing to find out about network quality by measuring several QoS parameters, namely *Throughput*, *Delay* and *Jitter*.

III. RESULTS AND DISCUSSION

A. Place and Time of Research

This research was conducted on Jalan Laksda Adi Sucipto, Blimbing, Malang City from December 2025 to June 2026. All stages of the research, including hardware design, software development, sensor calibration, system testing, data collection, and analysis of test results, were conducted at the location. Data collection was carried out directly on the prototype of the Internet of Things (IoT)-based cricket cultivation system that had been designed.

B. Design Results and Implementation of Tools

The implementation phase is carried out after the entire hardware and software design process is complete. The implementation aims to realize the design of a wireless sensor network-based cricket cultivation monitoring and control system. The results of the tool implementation are shown in Figure 3.



Figure 3. Tool implementation results

Figure 3 illustrates the overall implementation of the developed monitoring and control system. The system consists of the ESP32 Node Client, which acquires data from the DHT22 sensor, LDR sensor, load cell, and RTC module, and the ESP32 Node Master, which functions as the gateway for transmitting data to the Firebase Realtime Database. The implementation also includes actuators, such as the heating lamp, mist maker, and servo motor, which are automatically controlled using the Mamdani Fuzzy Logic algorithm. This successful integration demonstrates that all hardware and software components operate together to provide real-time monitoring and automatic environmental control for cricket cultivation. When the ESP32 Master has not yet been configured or fails to reconnect to the previous network, the

WiFiManager portal automatically appears, as shown in Figure 4.

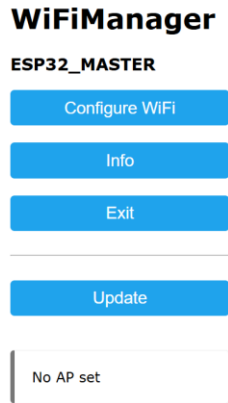


Figure 4. WiFiManager home page view

Figure 4 shows page beginning WiFiManager appears when ESP32 Master is not yet own configuration network or fail connected to the network previously. Through page the users can select the Configure WiFi menu. For do configuration network. After selecting the Configure WiFi menu, users are directed to the WiFi configuration page shown in Figure 5, where the SSID and password are entered.

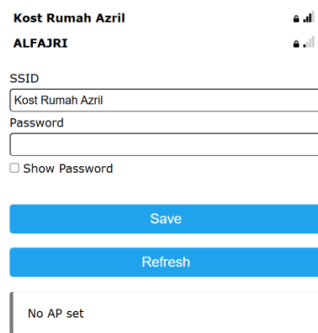


Figure 5. Example of the WiFi SSID and password configuration page

Figure 5 shows page configuration WiFiManager used For choose Wi-Fi network as well enter the password. After knob **Save** pressed, configuration network will stored in the ESP32 memory so No need configured return during same network Still available. Once the WiFi credentials have been saved successfully, the ESP32 Master connects to the selected wireless network, as shown in Figure 6.

```
19:42:43.061 -> *wn:Connecting to NEW AP: Kost Rumah Azril
19:42:43.061 -> *wn:connectTimeout not set, ESP waitForConnectResult...
19:42:47.285 -> *wn:Connect to new AP [SUCCESS]
19:42:47.285 -> *wn:Got IP Address:
19:42:47.285 -> *wn:192.168.100.41
19:42:48.285 -> *wn:config portal exiting
19:42:48.285 -> =====
19:42:48.329 -> WiFi Connected
19:42:48.329 -> IP ESP32 Master : 192.168.100.41
19:42:48.329 -> =====
19:42:48.329 -> mDNS responder Aktif: http://esp32master.local
```

Figure 6 Results of ESP32 master connection using WiFi manager

Based on Figure 6, ESP32 Master is successful connect to the selected Wi-Fi network through WiFiManager. After connection success, device get IP address in automatic from

the router, then activate service mDNS so that can accessible use address <http://esp32master.local>.

C. Mamdani Fuzzy Logic Algorithm Test Results

The Mamdani Fuzzy Logic algorithm test aims to evaluate the system's ability to determine the operating duration of the heating lamp and *mist maker* based on a combination of temperature and humidity values obtained from the DHT22 sensor. The test was conducted using 25 data samples collected over five days at different observation times. The test results show that the system is able to provide an adaptive response to changes in environmental conditions. When the temperature is below ideal conditions (around 24–25°C) with low humidity, the system automatically increases the operating duration of the heating lamp and *mist maker*. Conversely, when the temperature and humidity approach optimal conditions for cricket cultivation (26–27°C and 75–76%), the operating duration of both actuators is reduced, resulting in more efficient energy use.

Algorithm validation is carried out by comparing the system output results to manual calculations using the Mamdani Fuzzy Logic method which includes the fuzzification process, inference using the MIN operator, rule composition with the MAX operator, and defuzzification using the Centroid method. One of the test samples at a temperature of 26.1°C and humidity of 76.5% produces a lamp duration of 6.13 seconds on the system, while the manual calculation result is 6.20 seconds so the difference is only 0.07 seconds. On the *mist maker actuator*, the system produces a duration of 2.59 seconds, while the manual calculation is 2.64 seconds with a difference of 0.05 seconds. This difference shows that the implementation of the algorithm on the microcontroller has results very close to the theoretical calculation. The summary of the Mamdani Fuzzy Logic algorithm testing results is presented in Table I.

TABLE I.
SUMMARY OF MAMDANI FUZZY LOGIC ALGORITHM TEST RESULTS

Parameter	Results
Number of test samples	25 data
Average error of heating lamp	1.62%
Average error of <i>mist maker</i>	1.58%
Combined system error	1.60%
Accuracy of Mamdani Fuzzy Logic algorithm	98.40%
Manual calculation difference (lights)	0.07 seconds
Difference in manual calculations (<i>mist maker</i>)	0.05 seconds

Overall, the error values across all samples were below 5%, ranging from 0.85–2.47% for the heating lamp and 1.15–1.89% for the *mist maker*. These values indicate that the implementation of Mamdani Fuzzy Logic is capable of producing consistent and stable control decisions. The small difference between the system results and manual calculations is mainly due to the *floating-point rounding process* in the microcontroller, so it does not have a significant impact on system performance. With an accuracy level of 98.40%, the Mamdani Fuzzy Logic algorithm has been proven capable of controlling the environmental conditions of cricket cultivation automatically, precisely, and

in accordance with the theoretical design. These results are also in line with previous studies that stated that the Mamdani Fuzzy method is effective in IoT-based environmental control systems because it is able to produce adaptive decisions to changes in sensor conditions (Adib et al., 2021; Hasyim & Jombang, 2025).

D. QOS (Quality of Service) Test Results

Quality of Service (QoS) testing is performed For evaluate quality Data communication on the Internet of Things (IoT) system that was built . Testing done use Wireshark application with method perform packet capture process on Then data traffic sent by the ESP32 device to Wi-Fi network. Packet capture was performed using Wireshark to record communication traffic between the ESP32 device and the wireless network. The packet capture process is shown in Figure 7.

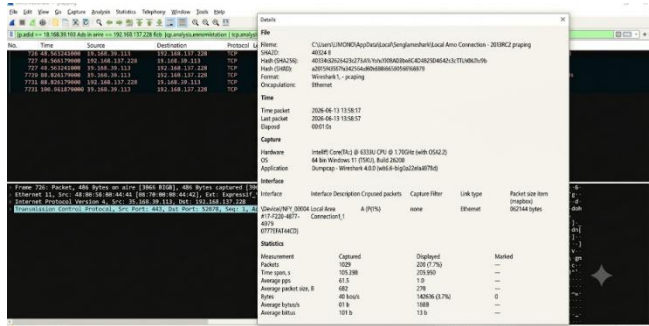


Figure 7. Packet capture view in wireshark

Figure 7 shows *packet capture* process results use Wireshark application at the time data communication between ESP32 devices and networking ongoing . Successful data packets recorded furthermore used as data sources in Quality of Service (QoS) analysis . In this study , the throughput parameters were obtained from information statistics results Wireshark *capture* , while the delay and jitter parameters are calculated manually using Microsoft Excel based mark *timestamp* every packages that have been recorded . With Thus , all QoS analysis using the result data same *capture* so that the measurement process become more consistent .

1) Delay Testing

The delay calculation results for the morning measurement session are presented in Table II.

TABLE II.
DELY PARAMETERS TEST RESULTS

Parameters	Results
Number of Packages	181
Total Time	29.4548408 s
Average	0.162733927 s
Delay	162,734 ms

The delay calculation results for the afternoon measurement session are presented in Table III.

TABLE III.
TEST RESULTS TEST RESULTS OF DELY PARAMETERS

Parameters	Results
Number of Packages	193
Total Time	29.445838 s
Average	0.152569109 s
Delay	152,569 ms

The delay calculation results for the evening measurement session are presented in Table IV

TABLE IV.
RESULTS OF DELY τ PARAMETER TESTING

Parameters	Results
Number of Packages	200
Total Time	34.3932642 s
Average	0.171966321 s
Delay	171,966 ms

The comparison of delay values obtained during different testing periods is summarized in Table V.

TABLE V.
DELAY PARAMETER PERFORMANCE TEST RESULTS

Testing Time	Delay (ms)
Morning	162.73
Afternoon	152.57
Evening	171.97

Based on Table V, the delay value obtained in the morning day of 162.73 ms , during the day day of 152.57 ms , while at night day increase to 171.97 ms. The lowest delay value happened during the day day , while mark highest obtained at night day . This shows that condition network at night day tend own time further delay big compared to morning and afternoon day . For make things easier interpretation results testing , the delay value is visualized in form chart the stem in Figure 8.

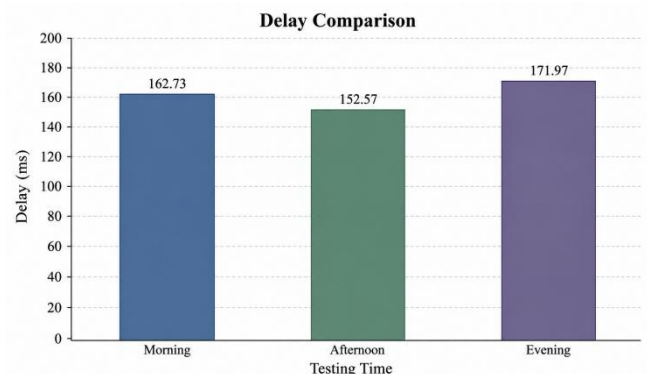


Figure 8. Bar plots delay comparison graph

Based on Figure 8 it can be seen that delay value experienced changes in each time testing . Based on Telecommunications and Internet *Protocol Harmonization Over Networks* (TIPHON) standard [42], delay value of 150–300 ms including in Good category . With Thus , the

results testing show that system Still own quality good communication so that capable supports the process of sending monitoring data in real-time.

2) Jitter Testing

The comparison of jitter values obtained during system testing is presented in Table VI.

TABLE VI.
JITTER PARAMETER PERFORMANCE TEST RESULTS

Testing Time	Jitter (ms)
Morning	60.13
Afternoon	78.30
Evening	101.51

Based on Table VI, the jitter value in the morning day by 60.13 ms , increasing to 78.30 ms at noon day , then return increase to 101.51 ms at night day . Lowest jitter value obtained in the morning day , while highest jitter value happened at night day . This shows that condition network at night day own variation time arrival more packages big compared to morning and afternoon day so that stability data transmission tends to decrease .

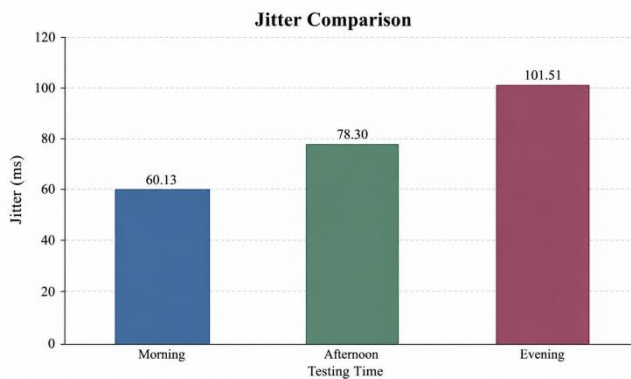


Figure 9. Bar plots comparison of jitter values

Based on Figure 7 it can be seen that jitter value experienced improvement from Morning until Evening day . Based on standard *Telecommunications and Internet Protocol Harmonization Over Networks* (TIPHON) [42], jitter value 0–75 ms including Good category , whereas value 75–125 ms including Medium category . Therefore , the results testing show that jitter value in the morning day (60.13 ms) still is at in Good category , while during the day day (78.30 ms) and night day (101.51 ms) is in Medium category . Although happen improvement variation time arrival packages during the day and night day , data communication between ESP32 device and fixed monitoring system can ongoing properly so that the sensor data sending process is still walk in a way continuous .

3) Testing Throughput

The throughput measurement results obtained during the morning testing session are shown in Table VII.

TABLE VII. THROUGHPUT TEST RESULTS ON WIRESHARK MORNING

Parameters	Results
Number of Bytes	49589
Time Span (S)	29455
THR (bytes/s)	1,684
bits/s	13.4684

The throughput measurement results obtained during the afternoon testing session are presented in Table VIII.

TABLE VIII.
THROUGHPUT TEST RESULTS ON WIRESHARK SIANG

Parameters	Results
Number of Bytes	51741
Time Span (S)	29446
THR (bytes/s)	1,757
bits/s	14.0572

The throughput measurement results obtained during the evening testing session are presented in Table IX.

TABLE IX.
THROUGHPUT TEST RESULTS ON WIRESHARK NIGHT

Parameters	Results
Number of Bytes	55265
Time Span (S)	34393
THR (bytes/s)	1,607
bits/s	12.8549

The overall comparison of throughput values for all testing sessions is summarized in Table X.

TABLE X.
THROUGHPUT PARAMETER PERFORMANCE TEST RESULTS

Testing Time	Throughput (Kbps)
Morning	13.47
Afternoon	14.06
Evening	12.85

Based on Table X, the throughput value in the morning day by 13.47 Kbps, an increase to 14.06 Kbps during the day day , then decrease to 12.85 Kbps at night day . Highest throughput value obtained during the day day , while lowest throughput value happened at night day . Difference the show that condition network at the moment testing influence capacity rate data transmission that can transmitted by the system .

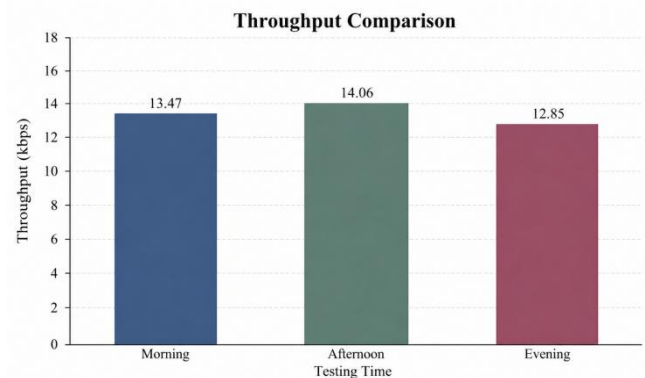


Figure 10. Comparison bar plots chart mark throughput

Based on Figure 8 it can be seen that throughput value experienced a little change in each time testing. Highest throughput value obtained during the day of 14.06 Kbps, while the lowest obtained at night of 12.85 Kbps. Although there is a difference in throughput value on all three time testings, the difference that occurs is relatively small so that shows that the system's own ability is sufficient for data transmission to be stable during the communication process. Based on the standard *Telecommunications and Internet Protocol Harmonization Over Networks* (TIPHON) [42], the value of *Throughput* including the Bad category

E. Discussion

1) Discussion of Cricket Cultivation Control System

The implementation results show that all hardware and software components were successfully integrated into an Internet of Things (IoT)-based cricket farming monitoring and control system. The system consists of a DHT22 sensor, an LDR sensor, a load cell sensor, a DS3231 RTC module, an ESP32 Node Client, an ESP32 Node Master, a Firebase Realtime Database, and a monitoring website that communicate with each other through a Wireless Sensor Network (WSN) architecture. This integration enables the process of monitoring environmental conditions and controlling actuators to take place automatically.

Temperature, humidity, light intensity, and weight data of the greenhouse are read by sensors and then processed on the ESP32 using the Mamdani Fuzzy Logic algorithm to determine the operating duration of the heating lamp and *mist maker*. Next, all data is sent to the Firebase Realtime Database via the ESP32 Node Master and displayed on the monitoring website in real-time. Thus, farmers can monitor cultivation conditions and actuator status centrally without having to conduct direct inspections at the cage location. The results of this implementation indicate that the developed system has met the research objectives, namely to provide automatic, integrated, and IoT-based monitoring and control of the cricket cultivation environment.

2) Discussion of Sensor Data Interpretation for Decision Making

Test results show that all sensors function as designed, providing reliable data for decision-making. The DHT22 sensor achieved 98.97% accuracy for temperature and 99.53% for humidity, providing highly accurate environmental information. The LDR sensor also successfully differentiates between dark, dim, and bright lighting conditions, allowing for automatic monitoring of lighting conditions within the greenhouse.

The load cell sensor produced a MAPE value of 0.65%, equivalent to an accuracy level of approximately 99.35%, indicating that the calibration process using linear regression can improve the accuracy of mushroom weight readings. Meanwhile, the DS3231 RTC module successfully maintained time synchronization with the reference, allowing the automatic feeding schedule to be run consistently. All sensor data is then sent to the Firebase Realtime Database and displayed on the monitoring website in real time, providing

users with quick information on cultivation conditions for decision-making.

3) Discussion of the Accuracy of the Mamdani Fuzzy Logic Algorithm

Tests show that Mamdani's Fuzzy Logic algorithm can adjust the duration of the heating lamp and *mist maker* based on changes in ambient temperature and humidity. When the temperature falls below ideal conditions, the system increases the actuator's operating time to return the ambient conditions to the desired range. Conversely, when the temperature and humidity approach optimal conditions, the actuator's operating time is automatically reduced, resulting in more efficient energy use.

Validation was performed by comparing the system output results with manual calculations using the centroid defuzzification method. The test results showed an average error of 1.60%, so that the algorithm accuracy level reached 98.40%. This value indicates that the fuzzification, Mamdani inference, and defuzzification processes have been well implemented on the ESP32 microcontroller. The small difference between the system results and manual calculations is mainly due to the floating-point rounding process during computation, so it does not have a significant impact on system performance. With a high level of accuracy, the Mamdani Fuzzy Logic algorithm is considered suitable for application as a decision-making method in an IoT-based cricket cultivation environmental control system.

4) Discussion of Quality of Service (QoS)

Test results show that data communication on the Wireless Sensor Network (WSN) runs smoothly, despite a decrease in signal strength as the distance between the ESP32 Client Node and the ESP32 Master Node increases. This decrease does not result in communication interruptions, as the RSSI value remains within the range capable of supporting stable data transmission.

The Quality of Service (QoS) evaluation showed that the delay value was in the range of 152.57–171.97 ms, so it is included in the Good category according to the TIPHON standard and still meets the needs of a real-time monitoring system. The jitter value ranged from 60.13–101.51 ms, which indicates variations in packet arrival times due to changes in network conditions, but data communication continued stably without affecting the monitoring process. Meanwhile, the throughput value was in the range of 12.85–14.06 kbps. Although based on the TIPHON classification it is included in the low category, this capacity is still adequate because the IoT system only transmits small sensor data, such as temperature, humidity, light intensity, and weight.

The successful transfer of all data to the Firebase Realtime Database and its automatic display on the monitoring website demonstrates the successful integration of the WSN, cloud services, and web interface. Thus, the system is capable of providing real-time, centralized, and reliable monitoring of cricket farming conditions, supporting automated environmental control processes.

IV. CONCLUSION

Gryllus bimaculatus cricket cultivation system based on a Wireless Sensor Network (WSN) was successfully developed using DHT22, LDR, load cell, and RTC DS3231 sensors integrated with ESP32 Node Client and ESP32 Node Master to monitor environmental conditions and schedule automatic feeding. Data on temperature, humidity, light intensity, clay barn weight, and time can be sent via the HTTP protocol, forwarded to the Firebase Realtime Database, and displayed on the monitoring website in real-time so that the monitoring process can be carried out centrally. The Mamdani Fuzzy Logic algorithm was successfully used to control warm lamps and *mist makers* based on temperature and humidity conditions with an accuracy level of 98.40%. In addition, the QoS test results show that data communication has a delay of 152.57–171.97 ms which is included in the good category based on the TIPHON standard, jitter of 60.13–101.51 ms, and throughput of 12.85–14.06 Kbps which is still able to meet the system's data transmission needs. Thus, the developed system is able to support automatic, integrated, centralized, and real-time monitoring and control of cricket cultivation.

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