Narrowband IoT in Livestock Farming: A Technological Innovation for Productivity and Sustainability

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Abstract.

The integration of technology in livestock farming is crucial for enhancing production efficiency and animal welfare. This study aimed to develop and evaluate the implementation of a Narrowband IoT (NB-IoT)-based automated monitoring system in poultry farming. Using an experimental design, the research involved 30,000 day-old chicks at PT. Anugerah Teknologi Ternak in Central Java, Indonesia. The NB-IoT system collected real-time data on environmental parameters and poultry activity. Time-series analysis revealed non-stationary data, while correlation analysis showed a strong negative relationship between temperature and humidity (r = -0.8521). Anomaly detection identified 13.33% of observations as anomalous, demonstrating the system's capability for early issue detection. Regression modeling (R-squared = 0.7261) indicated that temperature and humidity significantly influence poultry productivity. The study concludes that NB-IoT implementation in poultry farming has significant potential for enhancing productivity through real-time monitoring and early anomaly detection, supporting more efficient and sustainable precision farming practices. However, limitations in data stationarity and sample generalizability suggest the need for further research to improve long-term predictions and broaden applicability across diverse farming contexts.

Keywords: *Narrowband IoT, precision livestock farming, poultry monitoring, environmental management and anomaly detection.*

1. INTRODUCTION

The integration of technology in the livestock sector is becoming increasingly crucial in response to the demands for enhanced production efficiency and animal welfare. A promising innovation is the implementation of the Narrowband IoT (NB-IoT) for livestock monitoring. This technology offers a practical solution to the limitations of manual monitoring systems, which are often inefficient and lack accuracy. With real-time data collection capabilities, the NB-IoT enables the early detection of health issues, more effective environmental condition monitoring, and optimal resource management. The application of this technology is expected to significantly improve livestock productivity and welfare, particularly in rural areas that are challenging to achieve using conventional technology [1], [2]. Nevertheless, the livestock sector continues to face significant challenges in monitoring and managing animal conditions. Manual monitoring systems exhibit limitations in response speed, accuracy, and human resource intensity, frequently resulting in delays in detecting changes in environmental conditions and animal health. This increases the risk of difficult-to-control disease outbreaks and reduces the efficiency of resource utilization, such as feed and water [3]. Consequently, technological solutions capable of providing real-time information are essential to support more rapid and accurate decision making.

This study aims to develop and evaluate the implementation of an NB-IoT-based automated monitoring system in the poultry farming sector. This study aimed to boost agricultural output by leveraging real-time data to improve environmental management and animal health on farms. Additionally, this study evaluates the effectiveness of the NB-IoT in detecting behavioral anomalies or health conditions of livestock to prevent more serious health issues.

Although IoT technology has been widely applied in various sectors, the specific utilization of the NB-IoT in poultry farming remains underexplored. Most previous research has focused on IoT technology in general, without considering the specific advantages of NB-IoT, such as wider coverage and improved energy efficiency [1], [2]. Furthermore, the literature reveals challenges in ensuring the reliability and quality of data obtained from automated systems, particularly in dynamic environments. This study aims to address these gaps by presenting an NB-IoT-based solution that is expected to make a significant contribution to the existing literature. This study provides a novel contribution by specifically applying the NB-IoT in automated monitoring systems for poultry farms, which has rarely been adopted in this sector. In addition to offering improved efficiency and productivity through real-time data collection, this system is designed to provide comprehensive insights into environmental conditions and livestock behavior. The justification for this research lies not only in its technological innovation but also in its practical impact on farmers, particularly in rural areas with limited access to advanced technological infrastructure [4], [5]. With this monitoring system, farmers can reduce livestock health risks, improve animal welfare, and optimize farm productivity.

II. METHODS

Research Design

This study utilizes an experimental design to develop and test an automated monitoring system based on Narrowband IoT (NB-IoT) for poultry farming. The system aims to monitor real-time health and environmental conditions in order to boost livestock productivity. Based on precision livestock farming principles, it employs sensors and IoT networks for automated data collection and analysis. The research phases included system design, implementation, testing, evaluation, and data collection and analysis.

Population and Sample

This study focuses on the poultry farming sector at PT. Anugerah Teknologi Ternak, located at Jl. Pesantren, Bojong, Prupuk Utara, Margasari, Tegal Regency, Central Java 52463, with a research sample involving 30,000 day-old chicks (DOC) in multiple coops. The selection of a large-scale sample aimed to evaluate the effectiveness of the NB-IoT monitoring system in poultry farming operations. Automated monitoring on a large scale has been demonstrated to provide more accurate results regarding livestock health and farm productivity [6].

Research Procedure

This research was conducted in the following stages.

1) System Design: The NB-IoT monitoring system was designed to measure the environmental parameters and poultry activity. The sensors utilized included temperature, humidity, and air quality measurements as well as poultry activity monitoring. The data were automatically collected and transmitted in real time via the NB-IoT network.
2) System Implementation: The system was implemented in multiple poultry houses equipped with sensors connected to the NB-IoT platform. This system continuously collects environmental and poultry health data, facilitating expeditious and precise data-driven decision making.
3) Testing and Evaluation: The system undergoes testing to ensure its accuracy in detecting changes in environmental conditions and poultry health. Tests were conducted over several periods to evaluate anomaly detection and early warning capabilities. This monitoring system is comparable to those employed in livestock behavior recognition using accelerometers, which have been proven effective in detecting behavioral anomalies[7].
4) Data Collection and Analysis: Data from sensors are automatically collected through the NB-IoT system and include temperature, humidity, air quality, and poultry activity. These data were subsequently transmitted to a centralized database for further analysis, similar to the approach utilized by Zhang and Ex (2022) in detecting distress vocalizations in chickens [8].

Data Collection

Data were collected through sensors connected to the NB-IoT system, with measured parameters including the coop temperature, humidity, air quality, and poultry activity. Data collection occurred automatically without manual intervention, with real-time data transmission to a centralized database. This technique followed the method employed by Tedeschi et al. (2021) to facilitate real-time data collection in precision livestock farming [9].

Data Analysis Techniques

1) The data were analyzed using several statistical methods to evaluate the impact of the monitoring system on poultry farm productivity.
2) Time-series analysis: This was used to evaluate changes in environmental conditions over time. A stationarity test using augmented Dickey (ADF) was conducted to determine whether the data were stationary or non-stationary. This technique is commonly employed in environmental monitoring of livestock farming [8].
3) Correlation Analysis: Correlation analysis was employed to measure the relationship between temperature and humidity and their impact on poultry productivity. The relationship between environmental conditions and productivity has been proven significant in various studies related to precision livestock farming [6].
4) Anomaly Detection: The Isolation Forest method was applied to detect anomalies that might indicate changes in health or suboptimal environmental conditions. This technique has been widely used for automated monitoring, as described by Tedeschi et al. (2021) [9].
5) Regression Modelling: Linear regression was used to evaluate the relationship between independent variables, such as temperature and humidity, with poultry productivity as the dependent variable. The R-squared value was used to measure the extent to which independent variables could explain productivity variation following the statistical approach commonly used in automated monitoring research.

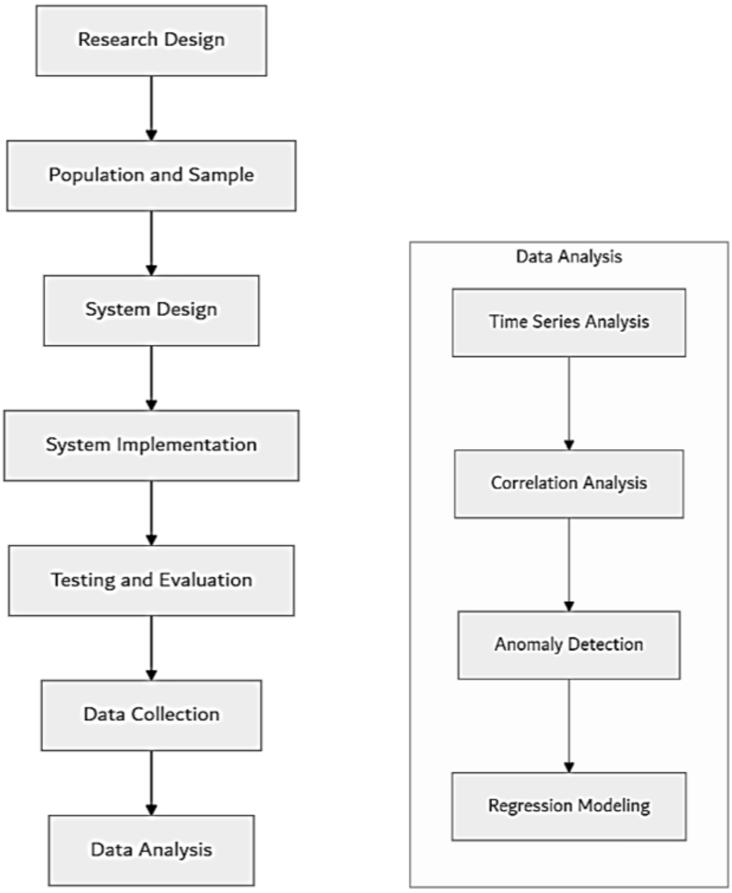

Fig. 1. Research Method

III. RESULT AND DISCUSSION

Following the implementation of the system, the data collection results clearly demonstrated changes in temperature and humidity throughout the observation period. Over time, a consistent decrease in temperature was observed, from approximately 30°C to 27°C. This decline remained consistent throughout most of the study period, indicating a gradual transition to cooler environmental conditions. Conversely, humidity exhibited an opposing trend. An increase in humidity from approximately 47% to nearly 60% was observed, signifying an elevation in the atmospheric moisture content as the temperature decreased. The relationship between these two variables provides insight into how temperature fluctuations may influence humidity within the observed environment.

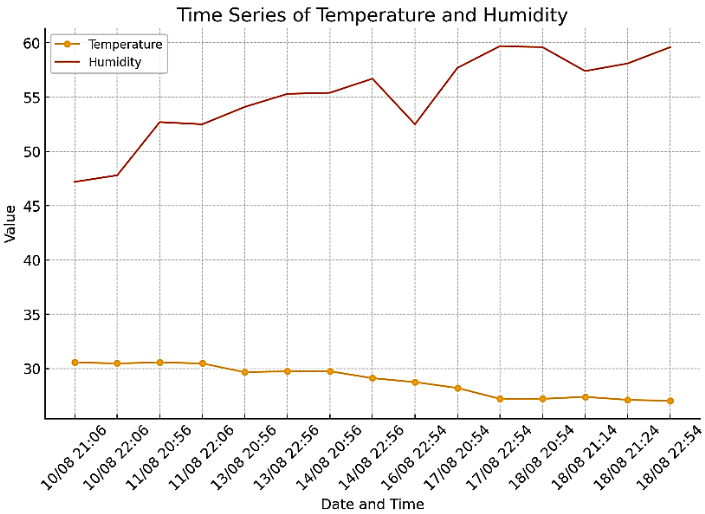

Fig. 2. Time Series of Temperature and Humadity

The Augmented Dickey-Fuller (ADF)[10] test shows that the data used are not stationary, with a p-value of 0.9770, indicating a pattern or trend that develops over time. This finding is in line with the literature which states that environmental data and livestock productivity are often influenced by seasonal factors and dynamic variables[11]. Non-stationarity in the data requires the application of more sophisticated modelling methods, such as differencing techniques or ARIMA models, to overcome these trends in long-term predictions.

In addition, the strong negative correlation between temperature and humidity (r = -0.8521) confirms the importance of proper environmental management on farms. Previous studies have also indicated that increasing temperature significantly reduces humidity, which can affect poultry health, increase the risk of heat stress, and decrease productivity [12], [13].

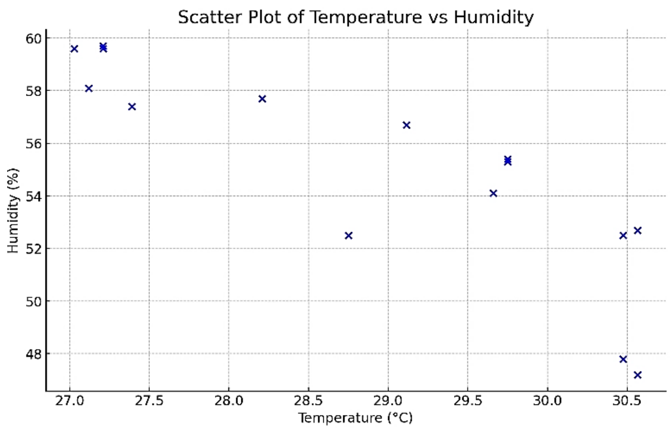

Fig. 3. Scatter Plot of Temperature vs Humidity

The anomaly detection successfully found 15 anomalous observations, with two of them being significant, and the percentage of detected anomalies in the data was approximately 13.33%. That is, approximately 13% of the observations were identified as anomalous by the model, underscoring the advantages of utilizing the NB-IoT in real-time livestock monitoring. This technology allows farmers to detect abnormal conditions early, manually reducing the risk of losses caused by undetected health problems [14], [15].

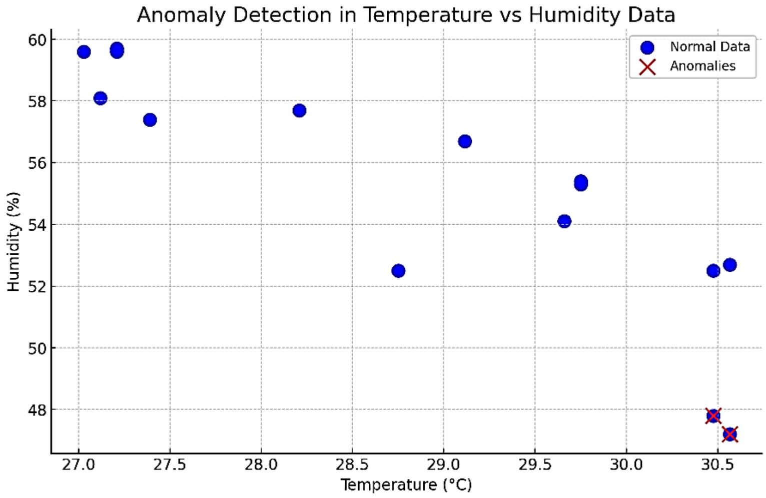

Fig. 4. Anomaly Detection

Further regression modelling, with an R-squared of 0.7261, showed that the temperature and humidity variables could explain most of the variability in poultry productivity.

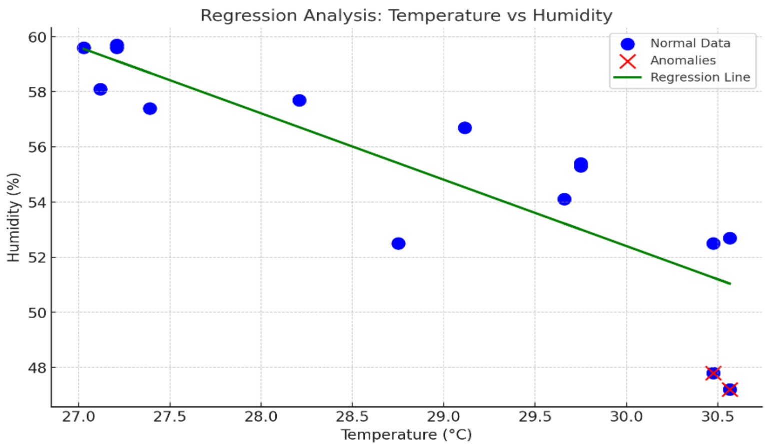

Fig. 5. Regression Analysis Visualisation

The R-squared value from the linear regression analysis quantifies how well the model explains the variation in the dependent variable (humidity) caused by the independent variable (temperature). This is the proportion of the total variation explained by the model[16]. R-squared ranged from 0 to 1, with 1 indicating a perfect explanation of the variation and 0 indicating none. An R-squared value of 0.726 indicated that 72.6% of the variation in humidity was explained by temperature. The negative regression coefficient (-2.4074) indicates that an increase in temperature leads to a decrease in poultry productivity, underscoring the need for optimal environmental conditions to enhance production yields. This research supports the link between well-managed microenvironments and improved livestock outcomes, aligning with prior findings on the importance of environmental monitoring in precision livestock systems[17].

This study contributes significantly to the development of theory and practice regarding the utilization of Narrowband IoT (NB-IoT) technology in precision livestock farming. Theoretically, this study expands the understanding of NB-IoT applications for real-time monitoring, anomaly detection, and optimal environmental management. While previous literature on IoT in the agricultural sector has demonstrated substantial potential for enhancing productivity through more accurate data integration, research on the specific application of NB-IoT in livestock farming remains limited [18]. This study addresses this knowledge gap by providing empirical evidence on how NB-IoT technology improves poultry production through the management of temperature and humidity levels, as well as the detection of anomalies that can reduce losses caused by undetected diseases.

This study demonstrates that implementing NB-IoT in automated monitoring systems offers significant benefits for farmers by stabilizing environmental conditions that affect livestock welfare and productivity. The negative correlation between temperature and humidity allows NB-IoT systems to help farmers proactively adjust conditions to prevent poultry stress, aligning with the literature on the impact of microclimate management on livestock yields [12], [13]. Additionally, NB-IoT's real-time anomaly detection of NB-IoT accelerates issue responses and enhances productivity consistency in the livestock industry. These findings highlight the importance of integrating technology into modern livestock management to improve efficiency and support sustainable livestock farming [17], [19].

However, this study had some limitations. First, time series analysis revealed non-stationary data, presenting challenges in long-term prediction without stabilization techniques, such as differentiation or advanced modeling (ARIMA), which improve prediction accuracy [11]. Second, the sample was limited to 30,000 day-old-chicks (DOC) from a single farm, restricting the generalizability of findings across the poultry sector. Variations in species and environmental conditions may yield different results, necessitating further research on their external validity. Third, the R-squared value of the regression model indicated that 27% of productivity variability remained unexplained, suggesting the influence of unaccounted variables, such as nutrition or feed quality.

Future research should employ advanced modeling techniques, such as ARIMA or VAR, for long-term trend analysis and machine learning for predictive accuracy [11]. Studies should also include various livestock species and farm locations to enhance the generalizability of the results. Considering the 27% unexplained productivity variability, future research should include additional factors, such as nutrition and livestock management.

Socially and ethically, the NB-IoT in animal husbandry can boost productivity for small-to medium-scale farmers, enhancing food security and local economic growth, particularly in rural areas. However, broader adoption requires adequate infrastructure and training, thus posing implementation challenges [14].

Ethically, the use of the NB-IoT has the potential to improve animal welfare through early disease detection and environmental condition improvements. However, intensive data collection raises questions about privacy and data management. Therefore, clear policies are necessary to ensure the ethical use of this technology in accordance with animal welfare principles [17].

IV. CONCLUSION

This research demonstrates that the implementation of Narrowband IoT (NB-IoT) in automated monitoring systems within the poultry farming sector has significant potential for enhancing productivity, particularly through real-time environmental condition monitoring and early anomaly detection. Correlation analysis between temperature and humidity revealed a strong negative relationship (-0.8521), emphasizing the importance of optimal environmental management in supporting poultry welfare and productivity. Regression modelling with an R-squared value of 0.7261 indicates that environmental variables, such as temperature and humidity, significantly influence poultry productivity, although other unexplained factors exist. These findings underscore the critical role of the NB-IoT in supporting more efficient and sustainable precision farming practices, especially in anomaly detection and responsive environmental management.

Nevertheless, this study has several limitations, including data non-stationarity and constraints in generalizing results to large-scale farming operations. Despite these limitations, NB-IoT has been shown to provide a practical solution for improving productivity through enhanced real-time data management.

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