The 11th Asian-Australasian Conference on Precision Agriculture (ACPA 11)
October 14-16, 2025, Chiayi, Taiwan

SMARTPHONE APPLICATION FOR REAL-TIME ENVIRONMENT MONITORING OF SMART GREENHOUSES

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Abstract

Smart greenhouse technologies significantly enhance agricultural productivity, sustainability, and resource efficiency, yet existing solutions often face limitations regarding affordability, real-time responsiveness, and scalability, especially for small- and medium-sized farms. This research introduces a cost-effective, scalable smartphone-based application designed for real-time monitoring and precise control of essential greenhouse environmental parameters, including temperature, relative humidity, CO2 concentration, and light intensity. The developed system consisted of 30 wireless sensor nodes utilizing LoRaWAN technology for robust data communication. These nodes transmitted sensor data through a LoRaWAN gateway to a ChirpStack network server, where backend data management was seamlessly handled by a microcontroller employing the FastAPI framework. The intuitive Android application provided dynamic, real-time, and historical environmental data visualizations, utilizing the MPAndroid Chart libraries to ensure user-friendly access. To enhance signal reliability, advanced signal processing techniques, including moving average and Kalman filtering, were employed, resulting in a notable reduction of sensor noise by approximately 97% ± 3% and an improvement in signal stability by about 95% ± 5%. An integrated anomaly detection algorithm successfully identified sensor malfunctions, environmental deviations, and actuator irregularities, promptly alerting users via push notifications, visual indicators, and audio signals. System performance evaluations demonstrated a high packet success rate and timely anomaly alerts within 10 ± 2s. Furthermore, MQTT protocols facilitated efficient bidirectional actuator control, significantly enhancing greenhouse management responsiveness.

Keywords: Precision agriculture, LoRaWAN, microclimate, MQTT, anomaly detection, spatial variability.

INTRODUCTION

Smart greenhouses improve productivity and resource efficiency through environmental monitoring (Maraveas et al., 2023). However, conventional monitoring approaches often suffer from high costs, limited scalability, and delayed responsiveness, which constrain their practical adoption. To address these challenges, this study developed a smartphone application with a

LoRaWAN sensor network to provide real-time monitoring and anomaly detection.

MATERIALS AND METHODS

The experimental setup used 30 sensing nodes equipped with commercial low cost temperature, humidity, CO_2, and light intensity sensors. Environmental control was achieved using brushless direct current (BLDC) fans, dehumidifiers, and a heating-cooling module. A smartphone application was developed using Android Studio for the visualization of real-time data and anomaly notification. Data was transmitted from sensors with the LoRaWAN gateway to a ChirpStack server, processed by a FastAPI backend, and communicated through MQTT in a local server to the smartphone application.

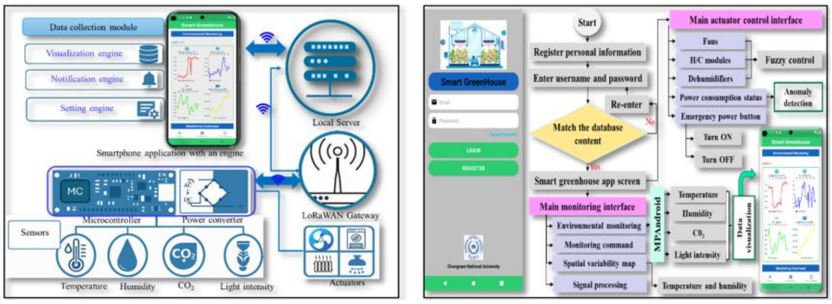

Fig.1 Wireless data transmission protocol of sensors to app vice versa (left side), and a smartphone application development chart for anomaly and data visualization (right side).

RESULTS AND DISCUSSION

The experimental results demonstrated a packet success rate exceeding 95%, with sensor noise reduced by 95 ± 3% and system stability enhanced by 95 ± 5%. Anomaly alerts were detected within 10 ± 2 seconds, ensuring timely monitoring and responsive control. These findings validate the feasibility, robustness, and scalability of the proposed approach for real-time smart greenhouse monitoring.

CONCLUSIONS

The proposed approach offered a reliable, low-cost solution for smart greenhouse monitoring, with future work directed toward predictive modeling and energy-efficient, scalable analytics.

ACKNOWLEDGEMENTS

This work was supported by Korea Institute of Planning and Evaluation for Technology in Food, Agriculture and Forestry (IPET), through Smart Farm Innovation Technology Development Program, funded by Ministry of Agriculture, Food and Rural Affairs (MAFRA) (Project No. RS-2024-00399854), Republic of Korea.

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