Journal of Information Technology and Computer Science (INTECOMS)
Volume 8 Nomor 4, Tahun 2025
e-ISSN : 2614-1574
p-ISSN : 2621-3249

PROTOTYPE OF CONDENSATION DETECTOR ON AIR HANDLING UNIT DUCTING BASED ON BLYNK AT JUWATA TARAKAN AIRPORT TERMINAL

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ABSTRACT

This research designs a prototype condensation detection system on Air Handling Unit (AHU) ducting at Juwata Tarakan Airport by utilizing Internet of Things (IoT) technology based on the Blynk platform. Condensation problems in AHU systems often cause water droplets that impact passenger comfort and safety, but there is no effective monitoring system for early detection. This system uses DHT11 and Raindrop sensors integrated with an ESP32 microcontroller, which will send temperature, humidity, and water presence data to the Blynk application in real-time. Test results show that the system is able to detect potential condensation quickly and accurately, and send notifications to technicians in less than two seconds. In addition to improving AHU maintenance efficiency, this system also supports increased security and comfort in the terminal area. This research is expected to be a practical solution for intelligent HVAC system monitoring in public facilities.

***Keywords**: AHU, condensation, Blynk, ESP32, DHT11 sensor, Raindrop, IoT*

INTRODUCTION

Airports are vital infrastructure that plays a role in supporting community mobility and economic growth in a region in accordance with PM 10 of 2024 (Muda, 2025). To maintain passenger comfort and safety, various supporting facilities must be well maintained, one of which is the air conditioning system. Air Handling Unit (AHU) is an important component in the HVAC (Heating, Ventilation, and Air Conditioning) system that functions to regulate air circulation in the airport terminal. However, in its operation, AHU often experiences condensation problems that can cause water droplets in the ducting system, thus causing disruption to passenger comfort and potential damage to facilities. Air Conditioner is a tool used to regulate or condition air quality which includes air circulation, regulating air humidity, regulating air cleanliness and to purify air (Labobar, 2024; Woodward et al., 2024).

Condensation problems are a common problem in AHUs. Condensation occurs due to an imbalance in temperature and humidity, which causes water vapor to turn into liquid on the surface of the ducting. Condensation water is water formed from the condensation process, where water vapor undergoes a phase transformation into a liquid. This includes water collected from the condensation process of air conditioning or other cooling systems (Pang et al., 2025). At Juwata Tarakan Airport, this phenomenon occurs without a dedicated monitoring system, so corrective actions are often reactive, based on reports from cleaning staff or facility users. This lack of control can worsen damage to building components and increase safety risks. Therefore, an early detection system is needed that can monitor the temperature, humidity, and presence of water in the AHU ducting in real time (Solihah et al., 2024).

The advancement of Internet of Things (IoT) technology enables the development of efficient, connected, and easily accessible monitoring systems. The Internet of Things, often known as IoT, is an embedded system that aims to expand the use of continuously connected internet connectivity (Li et al., 2023). This study aims to design and implement a prototype of a Blynk-based condensation detection system integrated into the AHU ducting at Juwata Tarakan Airport Terminal. A prototype is an initial version of the software used to demonstrate concepts, try various design options, and explore more problems and solutions (Barbiero et al., 2023).

In order to optimize maintenance and prevent damage to the Air Handling Unit (AHU) ducting line, the author took the initiative to overcome these obstacles by raising the title "PROTOYPE OF CONDENSATION DETECTION SYSTEM IN AIR HANDLING UNIT DUCTING BASED ON BLYNK AT JUWATA TARAKAN AIRPORT TERMINAL". This tool is made by modifying the water sensor and DHT11 with a connector using ESP32 as a WiFi module so that it becomes a tool that can be used as a real-time monitoring media via an internet connection to aviation technicians (Maimun et al., 2025).

METHODOLOGY

Method of Collecting Data

The research design is like an internal map that will guide the researcher to the objectives of the research (Popov et al., 2023). In this research design, there is a data collection method explaining the procedures for collecting data. In this study, the data collected by the author is through observation and documentation. The data was collected by the researcher directly from the primary source or the place where the research object was conducted. The researcher used the results of observations obtained from the research location regarding the research topic as primary data. According to (Ashraf & Heavey, 2023) primary data is a data source that directly provides data to the data collector (Dania et al., 2023; Rygał et al., 2025) secondary data is a data source that does not directly provide data to the data collector, for example through other people or through documents. In this study, the secondary data sources are books, journals, articles related to what is directly related to the research topic with other reference sources (Ceccarelli et al., 2024; Popov et al., 2023).

Data Processing

Data processing methods are data processing techniques that process data so that the data has meaning to answer problems and is useful for testing hypotheses or research questions (Flamini et al., 2023). This process includes activities such as data collection, cleaning (data cleaning), transformation, analysis, and interpretation of results. The choice of data processing method depends on the type of data, the purpose of the analysis, and the tools used, such as statistical software, spreadsheets, or programming programs. With proper data processing, the resulting information can be used for decision-making, problem-solving, or developing more effective strategies in various fields (Das et al., 2025; Retuerto & Andrade-Arenas, 2023).

Data Analysis

Data analysis is a part that must be done by a researcher in completing his research project [9]. Data analysis techniques are the process of systematically searching and compiling data obtained from observations, field notes and documentation, by organizing data into categories, describing them into units, synthesizing, arranging them into patterns, choosing what is important and what will be studied, and making conclusions so that they are easy to understand by oneself and others. Looking for references related to the series and materials (Dania et al., 2023; Rygał et al., 2025; Theologou et al., 2024). There are three stages in data analysis in this study, namely: Data Reduction, Data Presentation (Data Display), and Conclusion Drawing (Conclusion Drawing/Verification).

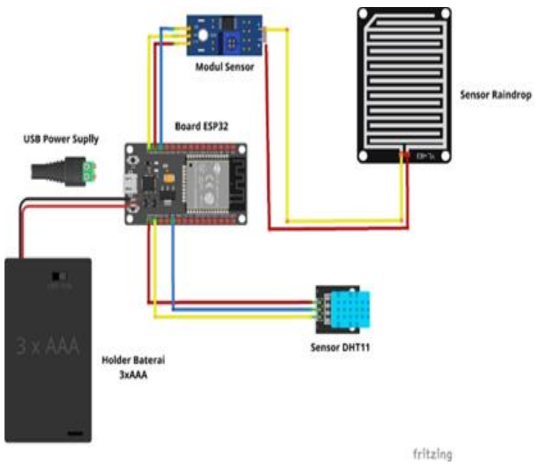
RESULTS AND DISCUSSION

This research has been conducted and can fulfill the researcher's objective to find out the results of the design made in CHAPTER 3 which consists of several stages, starting from component assembly, testing of each supporting part of the system to testing the system as a whole. From the results of interrelated tests to the performance of each part of the system that are interconnected so that a Prototype of Condensation Detection System is formed on the Blynk-Based Ducting Air Handling Unit (AHU) at the Juwata Tarakan Airport Terminal.

Picture1. Mock Up AHU as a media Prorotype of ducting condensation detection system

An Air Handling Unit (AHU) mockup is a physical or visual representation of an AHU system designed to provide a comprehensive overview of the function, configuration, and layout of its components before the actual unit is manufactured or installed. These mockups are typically used in the planning and coordination stages of construction projects, particularly in high-rise buildings or industrial facilities, to ensure that the AHU design meets technical requirements, health standards, and operational efficiency. An AHU mockup displays key components such as air filters, cooling and heating coils, blower fans, dampers, and a control system that regulates airflow and temperature. These mockups are made using representative materials, such as galvanized zinc as the main body structure, 1-millimeter-thick aluminum angle strips for the support frame and edge details, and ducting made from pipes to simulate airflow paths. Furthermore, miniature terminals or air outlets are made from acrylic for a more precise and aesthetic appearance. By evaluating these mockups, potential technical and design issues can be identified early, thereby reducing the risk of installation errors, increasing project time and cost efficiency, and ensuring the AHU system is truly optimally installed and meets specifications (Bychkov et al., 2024; Yu et al., 2023).

The results of the research on the condensation detection system show that the developed system is able to effectively detect the formation of condensation on surfaces using microcontroller-based humidity, temperature and water sensors. This system works by measuring the difference between surface temperature and dew point temperature, then providing an early warning if the condition is approaching the condensation threshold. Tests were conducted in various environmental conditions and showed as expected in predicting the risk of condensation, which can prevent damage to electronic devices, building surfaces, or HVAC systems. With the integration of a simple user interface and real-time monitoring capabilities, this system is considered suitable for application in industrial and residential environments.



Picture 2. Blynk-based condensation detector prototype circuit

A condensation detection sensor, located on the diffuser or air outlet of the ductwork, detects the presence of water vapor or dew point, which can cause condensation on the surface of the air duct. This condensation typically occurs when cold air from the Air Handling Unit (AHU) system meets warmer, more humid room air, which can cause water droplets around the diffuser. If left unchecked, these droplets can cause ceiling damage, mold growth, and even deterioration of indoor air quality.

Picture 3. Placement of the sensor near the AHU ducting

Trial Data Testing

TestingESP32 Board Performance

Testing the ESP32 board showed that it performed well even at 4.5V input, which is slightly below the recommended 5V. The board powered up and performed its functions, but efficiency and stability could be affected by power supply conditions. Wi-Fi connections on the 2.4GHz network were fast, averaging only 3–5 seconds to connect, although performance still depends on signal strength and distance from the router.

Table 1. ESP32 Performance Testing

Test Parameters	Test Conditions	Observation result	Information
Input voltage	4.5 V (3x1.5V AA batteries)	Board is on	Below the ideal voltage recommendation (5V)
WiFi Connection	Stable 2.4GHz WiFi network	Connect in 3-5 seconds	Depends on signal strength and distance of router
Communication with the DHT11 sensor	DHT11 is connected to GPIO pin 4	Temperature & humidity data is read correctly	Read every 5 seconds
Communication with RAINDROP sensor	The sensor is connected to GPIO pin 32	Detect water and send status to Blynk	Synced in <2 seconds
Connection to Blynk App	Blynk library installed, code uploaded successfully	Temperature, RH, and water status are displayed on the dashboard.	Requires a stable internet connection

Power Supply Testing

Test results show that within a usage duration of up to 20 minutes, the system works optimally with an initial voltage of 4.50 V which only drops slightly to 4.43–4.47 V, while maintaining a stable WiFi connection and normal sensor response. Temperature, humidity, and water status data can be displayed properly via the Blynk application, indicating the system is still within a safe working range. However, at the 30th minute, even though the voltage is still within reasonable limits (4.38 V), a delay in the WiFi connection begins to appear, affecting the speed of sending notifications to the application. When the usage time reaches 40 minutes, the voltage drop to 4.30 V causes the connection to become unstable, and the sensor response decreases, indicating the system is starting to lose work efficiency due to power reduction.

Table 2. Power Supply Stability Testing

Usage Time (minutes)	WiFi Connection Status	Sensor Response	Blynk App Status
10	Stable	Normal	Data displayed
20	Stable	Normal	Data displayed
30	Sometimes delay	Normal	Slow notification
40	Unstable	Less responsive	Data Displayed
50	Stable	Stable	Data displayed
60	Stable	Less responsive	Slow notification

Raindrop Sensor Response Testing

The Raindrop sensor testing aimed to assess the sensor's sensitivity to the presence of water on its surface and observe the system's integration with the Blynk application in providing condensation notifications. In the initial conditions from 09:00 to 09:05, the sensor surface was dry to slightly damp. The digital output was at HIGH (1), with output voltages of 3.3 V and 2.7 V, indicating no condensation was detected, so the system did not send a notification to the Blynk application. The sensor's response became more consistent when the surface was evenly wet (09:15) and fully wet (09:20), with the voltage dropping drastically to 0.5 V, and the "Fully detected" status activating continuous notifications and adding event logs to the application. At 09:25, after the water was removed until the surface was half dry, the output returned to HIGH (1) and the voltage rose to 2.9 V, indicating that the sensor was able to accurately identify the absence of water.

Table 3. Raindrop Sensor Response Testing to Water

Test Time	Sensor Surface Condition	Digital Output	Response to Blynk App
09:00	Dry, no water	HIGH (1)	No notification
09:05	Light moisture	HIGH (1)	No notification
09:10	Small water droplets (1–2 drops)	LOW (0)	Notification appears
09:15	Evenly wet	LOW (0)	Notifications + event log
09:20	Fully wet (rain simulation)	LOW (0)	Notifications are always active
09:25	Half dry (water removed)	HIGH (1)	Notifications stop

DHT11 Sensor Testing

The DHT11 sensor module contains a resistance element similar to a temperature measuring device such as NTC[11]. The DHT11 sensor was tested to observe the device's ability to detect changes in temperature and humidity, which are early indicators of condensation. The data obtained showed a gradual increase in humidity from 65% at 10:00 to 82% at 10:30, with the temperature also increasing from 25.3°C to 27.8°C. Under these conditions, the sensor showed stable performance with a "Normal" status throughout the data collection period, indicating that the device was able to read environmental parameters accurately and responsively.

Table 4. DHT11 Sensor Data Response Testing

Data Collection Time	Temperature (°C)	Humidity (%)	Sensor Status
10:00	25.3	65	Normal
10:10	26.0	70	Normal
10:20	27.2	78	Normal
10:30	27.8	82	Normal
10:40	26.4	74	Normal

Data Analysis Results

Based on the results of data from a series of trials that have been conducted, in-depth research shows that the condensation detection system circuit works well and meets the author's expectations and achieves maximum performance for all its components, here are some results after analyzing the research data. Based on the results of data from a series of trials that have been conducted, in-depth research shows that the condensation detection system circuit works well and meets the author's expectations and achieves maximum performance for all its components, here are some results after analyzing the research data. General and overall system performance, the developed condensation detection system shows very good performance in identifying and monitoring environmental conditions around the Air Handling Unit (AHU) ducting. The reliability of communication and notification systems is proven to be quite high in this prototype. The ESP32 module can connect to a WiFi network in an average of 3–5 seconds and consistently maintains connectivity as long as the power source is sufficient. Tests on the power supply system show that the use of three AA batteries (4.5V total) can run the system well for up to about 20 minutes, but there is a decrease in performance after 30–40 minutes. Modifications to the Raindrop sensor in the form of adding a zig-zag lead path on the panel surface have been proven to increase sensitivity and effectiveness in detecting water droplets due to condensation.

Product Revision

Based on testing and data analysis, several weaknesses in the system were identified that require improvements to ensure the device performs more optimally, reliably, and efficiently in a real-world operational environment. The proposed product revisions are as follows:

• Hardware Revision: The system experiences a performance drop after use for more than 30 minutes due to decreasing battery voltage. To address this, the system needs to be revised by replacing the AA batteries with a more stable external power supply module, such as a 5V power bank or DC adapter.

• Software Revision: It was found that the Raindrop sensor still had the risk of giving false signals in high humidity conditions without the presence of water. To reduce reading errors, the system needed to be improved by adjusting the data processing logic, namely by synchronizing the readings of the Raindrop and DHT11 sensors.

Discussion of Research Results

The results of the study show that the designed condensation detection system works effectively and in accordance with its initial objectives, namely monitoring temperature and humidity conditions and detecting the presence of water in real-time in the Air Handling Unit (AHU) ducting. The DHT11 sensor placed inside the ducting successfully recorded changes in temperature and humidity stably, while the Raindrop sensor installed in front of the diffuser was able to detect the presence of water quickly when condensation occurred. In terms of system reliability, the use of the ESP32 microcontroller has proven to be able to bridge communication between the sensor and the application smoothly. The process of sending data to the Blynk application is fast with an average notification delay of under two seconds, as long as the internet connection is stable.

Technically, the successful integration of the Arduino Mega microcontroller, proximity sensors, relays, and contactors demonstrated that system modifications could be made with affordable and widely available components. The designed control system proved reliable in two operating modes, providing flexibility in the field. This validated the solution. In addition to the system's core performance, modifications to the Raindrop sensor design significantly improved the device's effectiveness. By adding zigzag-shaped lead lines to the sensor's surface, sensitivity to water droplets was increased, allowing the sensor to distinguish between high humidity and the actual presence of water.

Research Implications

Based on research and testing of the Blynk-based condensation detection system for ducted Air Handling Units (AHUs) at Juwata Airport in Tarakan, this device has several important implications for airport operations and facility management. The implications that can be directly applied are as follows:

• Improving AHU Maintenance Efficiency allows airport technicians to remotely monitor temperature, humidity, and water availability through an application.

• Maintaining Passenger Comfort and Safety With early detection of condensation, the potential for water droplets that could cause slippery floors or damage airport interiors can be prevented.

• Encouraging the Implementation of IoT Technology in Facility Management so that this can be the beginning of the implementation of other smart systems in airport building management, such as automatic and integrated monitoring of energy, lighting, and ventilation systems.

CONCLUSION

Based on the design, testing, and data analysis results of the Blynk-based condensation detection system for the Air Handling Unit (AHU) ducting implemented at Juwata Tarakan Airport, it can be concluded that the system successfully met the research objectives and functioned optimally. The main conclusions of this study are as follows:

• The system is capable of detecting temperature, humidity, and water droplets in real-time. By using the DHT11 sensor and Raindrop sensor integrated with the ESP32 microcontroller, the system can monitor ducting environmental conditions and detect condensation accurately and send notifications directly through the Blynk application.

• The use of IoT technology improves AHU maintenance efficiency. System integration with the Blynk platform allows technicians to perform remote monitoring, reducing manual inspections and taking preventive measures faster before damage occurs.

• Modifications to the Raindrop sensor and adjustments to the power supply improve the system's effectiveness. Adding lead wires to the Raindrop sensor increases its sensitivity to water, while using an adapter or power bank instead of batteries improves system stability for long-term monitoring.

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