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Smart Building Design Web based Room Temperature and Humidity

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ABSTRAK

Pemantauan kondisi suhu dan kelembaban ruangan secara real-time menjadi aspek penting dalam mendukung kenyamanan dan efisiensi energi dalam gedung pintar (smart building). Penelitian ini bertujuan untuk merancang dan membangun sistem monitoring suhu dan kelembaban ruangan berbasis web yang terintegrasi dengan perangkat Internet of Things (IoT). Sistem ini menggunakan sensor DHT22 untuk mengukur suhu dan kelembaban, mikrokontroler ESP32 untuk mengirimkan data secara nirkabel melalui koneksi Wi-Fi, serta antarmuka web untuk menampilkan hasil pengukuran secara real-time. Data yang diperoleh tidak disimpan dalam database, namun ditampilkan secara dinamis pada web setiap kali halaman diakses atau di-refresh. Rancang bangun sistem ini juga dilengkapi dengan perancangan fisik kotak alat menggunakan perangkat lunak Autodesk Inventor, sehingga sistem dapat ditempatkan dengan rapi dalam lingkungan ruangan. hasil menunjukkan bahwa sistem mampu menampilkan suhu dan kelembaban secara akurat dan stabil. Implementasi sistem pada sebuah ruangan memperlihatkan keberhasilan sistem dalam membaca kondisi lingkungan dengan baik. Penelitian ini diharapkan menjadi dasar dalam pengembangan sistem monitoring lingkungan berbasis web yang lebih lanjut, termasuk penambahan fitur alarm pada suhu dan kelembaban yang melebihi ambang batas.

Keywords:

Smart Building
Internet of Things
Temperature and Humidity
Web Monitoring

ABSTRACT

Real-time monitoring of room temperature and humidity conditions is an important aspect in supporting comfort and energy efficiency in smart buildings. This research aims to design and build a web-based room temperature and humidity monitoring system integrated with Internet of Things (IoT) devices. This system uses a DHT22 sensor to measure temperature and humidity, an ESP32 microcontroller to transmit data wirelessly via a Wi-Fi connection, and a web interface to display real-time measurement results. The data obtained is not stored in a database, but is displayed dynamically on the web every time the page is accessed or refreshed. The design of this system is also complemented by the physical design of the toolbox using Autodesk Inventor software, so that the system can be neatly placed in a room environment. The results show that the system is able to display temperature and humidity accurately and stably. Implementation of the system in a room shows the success of the system in reading environmental conditions well. This research is expected to be the basis for further development of web-based environmental monitoring systems, including the addition of alarm features at temperatures and humidity that exceed the threshold.

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1. INTRODUCTION

The rapid development of information and communication technology in the last two decades has encouraged various sectors to carry out digital transformation, and construction and building management are no exception [1], [2]. The smart building concept is emerging as an innovative solution to improve energy efficiency[3], [4], [5], occupant comfort, as well as building security through the integration of Internet of Things (IoT) technology [6], [7] automation systems, and web-based digital platforms [8], [9], [10]. One important aspect of a smart building system is the ability to monitor and control indoor environmental conditions, particularly temperature and humidity parameters [11], [12], [13]. These parameters greatly affect occupant thermal comfort, health, and the efficiency of electronic equipment and air conditioning systems. In certain environments such as server rooms, laboratories, and storage rooms, uncontrolled temperature and humidity fluctuations can cause damage to devices and data, and increase operational costs [14], [15], [16], [17].

However, in practice, there are still many buildings in Indonesia, both office buildings, educational institutions, and public facilities, that have not implemented an automatic and real-time temperature and humidity monitoring system. Conventional systems that are still manual and not integrated complicate the monitoring process, and are unable to provide notifications or data visualization quickly and accurately.

To answer these challenges, this research designed and built an integrated room temperature and humidity monitoring system in the smart building concept. The system uses a digital temperature and humidity sensor (DHT22), an ESP32 microcontroller as the data processor and link to the internet, and a web-based interface that allows users to monitor data in real-time from any device connected to the network. The advantages of the developed system include ease of installation, relatively low implementation costs, online monitoring capabilities, and the potential for further development towards automatic control systems, historical data analysis, and integration with the overall building management system.

Thus, the objectives of this research are to, design a room temperature and humidity monitoring system that can be accessed in real-time via a web platform. Build a prototype based on ESP32 microcontroller and DHT22 sensor integrated with IoT system. Provide environmental data visualization that is informative and easy for users to understand. The results of this research are expected to be an initial solution towards a smart building system that is more intelligent, efficient, and adaptive to the needs of the modern environment.

2. RESEARCH METHODS

This research uses a research and development approach with the main stages including system requirements analysis, hardware and software design, prototype implementation, and functional testing and system evaluation. This approach was chosen because the main focus of the research is to produce a real system that can be used to monitor room temperature and humidity in real-time based on the web.

2.1 Overall System Block Diagram

The system is designed with an integrated structure between hardware and software. Class Room, is the physical location where the system is installed and the environmental conditions (temperature and humidity) are monitored, the sensor will take data from the air in this room. DHT22 (Temperature & Humidity) Sensor, Measures the temperature and humidity of the air in the room. DHT22 is a digital sensor that has a high level of accuracy and is able to measure temperature: -40°C to 80°C (±0.5°C) Humidity: 0%-100% RH (±2-5%), Data from this sensor is sent to the microcontroller. The ESP32 microcontroller, receives data from the DHT22 sensor and sends it via Wi-Fi network to the web. The ESP32 has Wi-Fi and Bluetooth connectivity, as well as ADC, GPIO, and Arduino IDE compatible features. Apart from being a data processor, the ESP32 can also perform: Format data before sending to

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the web (JSON, string, etc.) Provide API (if required) or local server. Wi-Fi, Connects the ESP32 microcontroller to the internet network. ESP32 utilizes Wi-Fi in order to transmit real-time data to the web server. Internet, becomes an intermediary medium so that ESP32 can connect with a web server that displays sensor data. A stable internet network is required so that data can be sent without delay. Website (Web Monitoring Interface), Displays real-time temperature and humidity data in a web interface. Can be accessed through a browser by users through the same network. Features that are usually available: Display of current temperature & humidity. Automatic data update every time the user opens or refreshes the page. This website does not store historical data (based on your previous information), it only displays the current reading from the sensor. The system block diagram can be explained as follows:

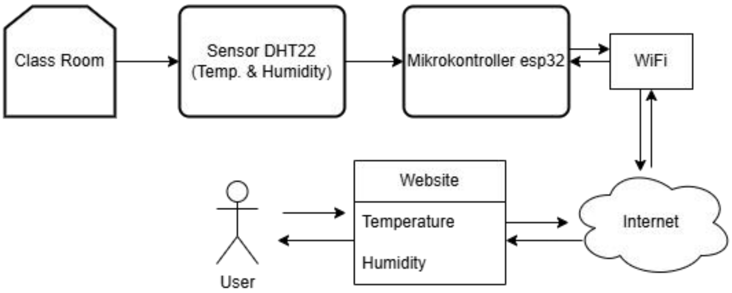

Figure 1: Workflow of the web-based room temperature and humidity monitoring system

2.2 Mechanical Design (Box Design)

To protect hardware components such as the ESP32, DHT22 sensor, and power supply module from dust, moisture, and physical interference, a device case or box design was created using Autodesk Inventor software. This design considers aspects of functionality, aesthetics, and ease of maintenance and installation indoors. In this smart building system, all electronic components such as the ESP32 microcontroller, sensors, and power supply modules are designed to be placed in one protective casing or box unit. The purpose of designing this box is to:

a. Protect components from dust, moisture, and physical interference,
b. Ensure air circulation so that temperature and humidity measurements are not distorted,
c. Simplify installation and maintenance of the system at the installation site.

The box design was created using Autodesk Inventor software, which enables precise three-dimensional modeling. The design has several important features:

a. Ventilation holes at the top to allow airflow into the sensor.
b. Transparent (acrylic) cover on the front to monitor the module status and indicator LEDs of the ESP32.
c. Four screw points for locking the case cover for easy opening during maintenance.
d. Port holes at the bottom for USB and power connections.
e. Rear mounting bracket (optional) for wall installation.

Here is a look at the 3D design of the device box:

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Figure 2: Box Design

2.3 Hardware Design

System development will start from designing the hardware that will be used to monitor the classroom, namely the ESP32 Module and DHT22 sensor. The use of the NodeMCU ESP32 module because it has a small size, is easy to write program code, has been integrated with the ESP32 WiFi module and so on so that it can be used as a wireless sensor network module. After analyzing the problem, the next step is to design the hardware. Hardware design serves to describe the use of appropriate devices to build a temperature and humidity monitoring system in the classroom. The hardware block diagram of the temperature and humidity monitoring system in the server room can be shown in Figure 3. While the circuit that has been implemented in the design box can be seen in Figure 4. There are 3 pins on the DHT sensor, pin out, pin ground and pin vcc. The pin out on the sensor is connected to the digital pin on the ESP32 Microcontroller, namely pin D4, the Ground pin on the sensor is connected to the microcontroller ground pin and then the vcc pin is connected to the 5 Volt microcontroller pin.

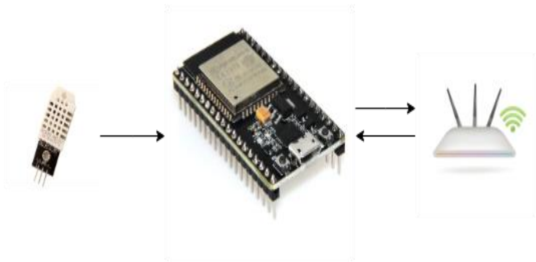

Figure 3: Hardware block diagram

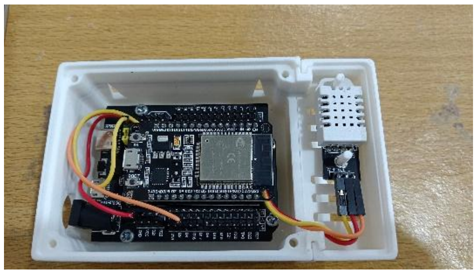

Figure 4: Tool Design with Box

2.4 Software Design

The software was developed in two main parts: microcontroller programming and web interface development.

2.4.1 Microcontroller (ESP32) Programming.

The ESP32 is programmed using the Arduino IDE with the following libraries:

a. DHT.h to read temperature and humidity sensor data,
b. WiFi.h to connect ESP32 to the network,
c. HTTPClient.h to send data to the server via HTTP protocol.

Steps:

a. Initialize the sensor and Wi-Fi connection (Getting IP).
b. Reads temperature and humidity from DHT22.
c. Get the mac address of the ESP3 microcontroller to enter on the website

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d. Obtain auth token for login automatically
e. Sends data to the local server (hosting PHP + MySQL) via HTTP POST request.

ESP32 will send data in JSON or form-data format to the PHP file on the server.

2.4.2 Web Design

On the server side, a PHP script was created to receive data from the ESP32 and save it to the MySQL database. The design of the web application director is by connecting the server with the user's computer via the internet network. Temperature and humidity sensor data will be sent to the database. describes how website components (client, server, database, and network) interact to provide services to end users. General System Workflow, ESP32 sends temperature and humidity data to the server (can be via API). The server stores the data into the database. The user opens the website through the browser. A request is sent from the client to the server for the latest data. The server retrieves the data from the database and returns it to the client. Data is displayed in real-time on the website interface.

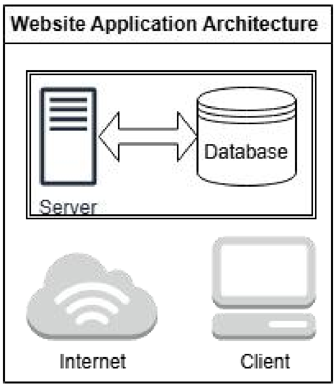

Figure 5: Web application architecture

3. RESULTS AND DISCUSSION

3.1 Overall System Implementation

The web-based smart building system designed in this research has been successfully implemented with the main components in the form of DHT22 sensors, ESP32 microcontrollers, local servers with PHP and MySQL, and web-based dashboards. The implementation is carried out in stages, starting from the hardware integration stage, software development, local system testing, to the actual implementation in the classroom. real-world implementation of a monitoring system on a room wall. The ESP32 module and DHT22 sensor are placed in a 3D printed protective case to protect the components from dust and physical interference, while still allowing air circulation for accurate measurements. The ESP32 module and DHT22 sensor have been mounted on the wall at a height of about 1.5 meters from the floor, following the standard placement of indoor environmental measuring instruments. This height was chosen to obtain a reading that is representative of the environmental conditions in which the user is located. When operated, the LED indicator lights up to indicate that the module is active and ready to send data to the server. The system is connected to a power source via an adapter and is powered on as evident from the red LED indicator.

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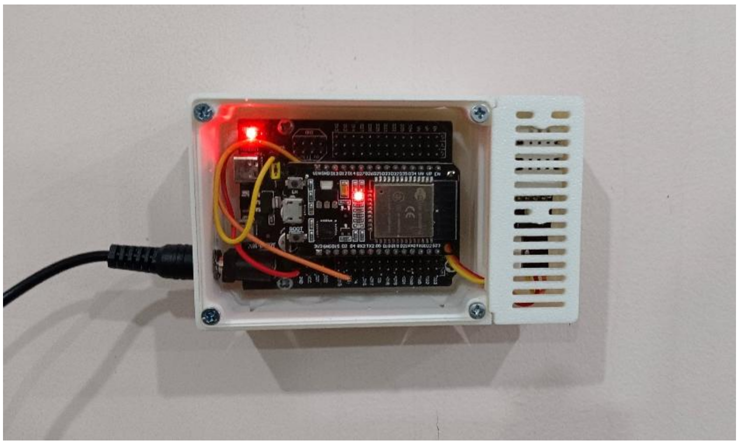

Figure 6: Tool Design with Box

The system works on the following principles:

1. The DHT22 sensor reads the air temperature and humidity in 7 second intervals.
2. The data is read by the ESP32 microcontroller and sent via Wi-Fi connection using the HTTP POST method to the local server.
3. The PHP script on the server side handles data parsing and saves it to the MySQL database.
4. The data is then retrieved by the web dashboard, displayed in numerical form.

Thus, users can remotely monitor room temperature and humidity conditions without having to physically access the device.

3.2 System testing

ESP32 Reading and Connection Results via Arduino Serial Monitor At the system testing stage, an initial monitoring process is carried out via Serial Monitor from the Arduino IDE to ensure that the ESP32 microcontroller can work in accordance with the expected functions. Here are some important results that were recorded, ESP32 Reading and Connection Results via Arduino Serial Monitor At the system testing stage, an initial monitoring process was carried out via Serial Monitor from the Arduino IDE to ensure that the ESP32 microcontroller can work according to the expected functions. Here are some important results that were successfully recorded: Successful Wi-Fi Connection After the system is powered on, the ESP32 successfully connects to the Wi-Fi network that has been specified in the Arduino sketch. The success of the WiFi connection is the main requirement for sending data to a web-based server or database. Obtaining IP Address from Router After a successful connection, the ESP32 is assigned a static or dynamic IP address by the router, which is used as an identity within the local network. This IP is also used for debugging purposes as well as API testing when accessed locally or through a browser, as can be seen in Figure 7.

```
rst:0x1 (POWERON_RESET),boot:0x17 (SPI_FAST_FLASH_BOOT)
configsip: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:1
load:0x3fff0030,len:4888
load:0x40078000,len:16516
load:0x40080400,len:4
load:0x40080404,len:3476
entry 0x400805b4
Menghubungkan ke WiFi......
Terhubung ke WiFi!
IP Address: 192.168.3.43
```

Figure 7: Connect to Wifi and Get IP

DHT22 Sensor Reading Successful the DHT22 sensor connected to ESP32 is able to provide temperature and humidity data periodically. Get the MAC Address of ESP32. For authentication or device identification purposes, the

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system prints the MAC Address of the ESP32, the MAC Address can be used to log devices accessing the server, or for additional security systems.

```
Server Response: 200
{"success":true,"message":"Suhu dan kelembaban berhasil diupdate","data":{"

=== Membaca Data Sensor ===
Suhu: 25.90 °C | Kelembaban: 59.20 %
Mengirim data ke server:
{"suhu":"25.90","kelembaban":"59.20","macAddress":"C0:5D:89:B1:54:80"}
Server Response: 200
{"success":true,"message":"Suhu dan kelembaban berhasil diupdate","data":{"

=== Membaca Data Sensor ===
Suhu: 26.00 °C | Kelembaban: 59.20 %
Mengirim data ke server:
{"suhu":"26.00","kelembaban":"59.20","macAddress":"C0:5D:89:B1:54:80"}
Server Response: 200
```

Figure 8: sensor and mac address readings

Authorization token Successfully Obtained, ine important feature in this system integration is the automatic authentication token sent by the server after the initial login process is successful. This token is required so that the ESP32 can send data to endpoints that require authentication. Data Sent to Server. With a stable connection and the token active, the ESP32 successfully sent data to the server.

```
rst:0x1 (POWERON_RESET),boot:0x17 (SPI_FAST_FLASH_BOOT)
configsip: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:1
load:0x3fff0030,len:4888
load:0x40078000,len:16516
load:0x40080400,len:4
load:0x40080404,len:3476
entry 0x400805b4
Menghubungkan ke WiFi......
Terhubung ke WiFi!
IP Address: 192.168.3.43
Respon Login:
"294|akRkMe34EstLC0au27J9KWDfNgGEquF7fBacRxiKa16d66dc"
Token berhasil didapatkan: 294|akRkMe34EstLC0au27J9KWDfNgGEquF7fBacRxiKa16d66dc
```

Figure 9: Auth token successfully obtained

All of these processes show that the ESP32 has functioned in accordance with its role as an IoT node that collects environmental data and sends it to the backend system via HTTP or HTTPS protocols. The ability to print data to a serial monitor is very important in the debugging stage before full system deployment. In addition to being an internal monitoring tool, the serial monitor also helps in the troubleshooting process such as connection failures or errors in the JSON payload.

3.3 Web Display and Reading Results

The results of the system implementation are shown in the Device Management dashboard, as in Figure 10 below:

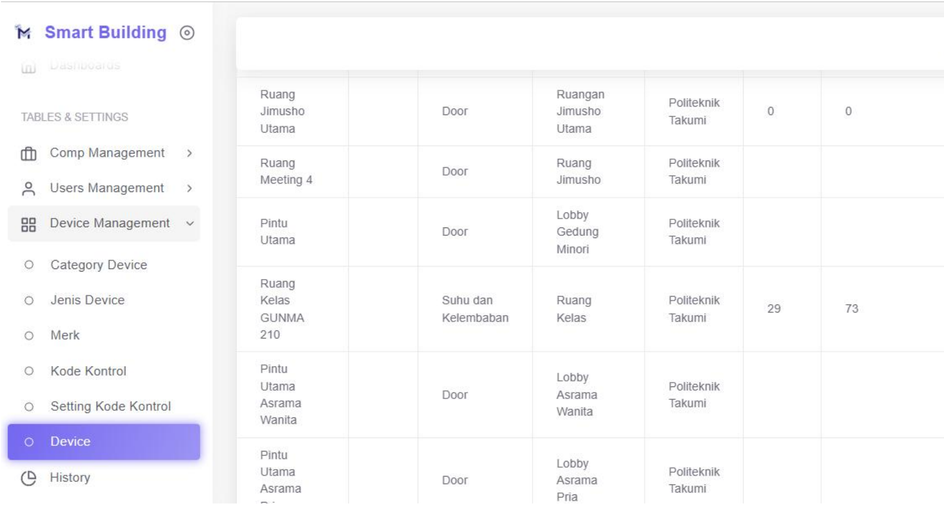

Figure 10: Web Dashboard View on Device Management Menu

In this view, it can be seen that, the device location is listed as GUNMA Classroom 210 at Takumi Polytechnic. The device category is "Temperature and Humidity". The read temperature value is 29°C and the humidity is 73%. The values are updated in real-time based on the last reading from the sensor, and are not stored in the database, so there is no data history that can be displayed in the form of graphs or time trends.

3.4 System Design Analysis

3.4.1 Excellence

1. The system minimizes the use of memory and server resources as it does not store data.
2. Sensor readings are displayed immediately so that users can see current data quickly.
3. Simple and responsive interface, perfect for instant monitoring needs.

3.4.2 Limitations

1. There is no data history or log function, making it impossible to analyze temperature and humidity trends.
2. There is no automatic alarm if the temperature or humidity value exceeds a threshold.
3. Manual refresh is required to update the latest data display.

4. CONCLUSION

Based on the results of the design, implementation, and testing of a web-based room temperature and humidity monitoring system in the context of smart buildings, it can be concluded that, The system was successfully designed and implemented using ESP32 microcontroller and DHT22 sensor, with real-time data transmission to MySQL-based server via WiFi connection. Hardware such as sensors and ESP32 module are able to work stably and continuously during the test period. The monitoring web interface provides easy access to data for users, allowing monitoring of room temperature and humidity using the same network. Thus, this system proves feasible to be used as an Internet of Things (IoT)-based technology solution to support the smart building concept, especially in the aspects of comfort and efficiency of indoor climate control.

future development of the system there is a warning in the form of an alarm that sounds when the temperature and humidity exceed a predetermined threshold. Improving the appearance of the web dashboard, by adding a graphical visualization feature of historical data.

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