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"DESIGN AND IMPLEMENTATION OF AN IOT BASED SMART COOLER"

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ABSTRACT

The IoT-Based Smart Cooler is an intelligent cooling system designed to provide energy efficient and automated temperature control using Internet of Things (IoT) technology. The research work aims to enhance user comfort, reduce manual operation, and optimize power consumption through real-time monitoring and smart automation. This system directly supports the objectives of sustainable and smart living by integrating modern sensor-based technologies with internet connectivity. The core architecture of the system consists of a microcontroller-based platform integrated with temperature and humidity sensors, cooling fans, water level sensors, and wireless communication modules. The system continuously monitors environmental conditions and automatically adjusts the cooling operation according to predefined temperature thresholds. Users can remotely monitor and control the cooler through a mobile application or web interface using IoT communication protocols.

The smart cooler employs sensors to collect real-time data regarding room temperature, humidity, and water availability inside the cooling unit. The collected data is processed by the controller, which intelligently regulates fan speed and water pump operation to maintain optimal cooling performance while minimizing unnecessary energy usage. Notifications and alerts are also generated when the water level becomes low or when maintenance is required.

The project further demonstrates the application of cloud-based IoT infrastructure for storing and analysing environmental data. Wireless technologies such as Wi-Fi or Bluetooth enable seamless communication between the hardware components and remote users. The system architecture ensures reliability, scalability, and low operational cost, making it suitable for homes, offices, and small-scale industries. The implementation and testing of the IoT-Based Smart Cooler confirmed successful automatic temperature regulation, remote accessibility, and efficient power management. The system provides a user-friendly, cost-effective, and environmentally sustainable solution for smart cooling applications while showcasing the practical integration of IoT technology in everyday appliances.

Keywords: *Smart cooler, Internet of Things (IoT), communication protocols, environmentally sustainable, ESP32 microcontroller, LCD display*

I. Introduction

Smart cooling systems are modern cooling solutions that use automation, sensors, and Internet of Things (IoT) technology to provide efficient temperature control and environmental monitoring. Traditional cooling systems require manual operation and consume more electrical energy due to the lack of intelligent control mechanisms. With the advancement of embedded systems and wireless communication technologies, smart cooling systems have become more efficient, userfriendly, and energy-saving. The development of IoT technology has enabled electronic devices to communicate through the internet and

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perform automated operations. In smart cooling systems, sensors are used to monitor environmental conditions such as temperature and humidity. Based on the sensor readings, the system automatically controls cooling devices like fans, pumps, or Peltier modules to maintain suitable temperature conditions. These systems can also be monitored and controlled remotely through mobile devices or web applications. The ESP32 microcontroller has become one of the most widely used platforms for IoT-based automation projects because of its built-in Wi-Fi and Bluetooth capabilities, low power consumption, and high processing performance. By integrating ESP32 with sensors, relay modules, LCD displays, and cooling mechanisms, a smart cooler system can be developed that provides automatic operation and realtime monitoring. Smart cooling systems are widely used in homes, offices, industries, greenhouses, and server rooms where temperature management is important. These systems help in reducing human effort, improving energy efficiency, and increasing user comfort. The IoT Based Smart Cooler project demonstrates the practical implementation of embedded systems, IoT communication, and smart automation technologies for modern cooling applications.

1.2 Purpose of the Project

The main purpose of the IoT Based Smart Cooler shown in Fig 1.1, is to develop an intelligent and energy-efficient cooling system that can be monitored and controlled remotely through Internet of Things (IoT) technology. The project is designed to provide automatic temperature monitoring and smart cooling control using the ESP32 microcontroller, sensors, and electronic control modules. This smart cooler system helps in maintaining a comfortable environment by automatically controlling cooling devices based on temperature and humidity conditions. The integration of IoT technology allows users to monitor system status and control operations through a web-based interface or wireless communication system. The project also air educe manual effort, improve energy efficiency, and demonstrate the practical implementation of embedded systems and automation technologies. Another important purpose of this project is to enhance learning and practical knowledge in the fields of electronics, embedded systems, IoT communication, sensor interfacing, and programming. The project provides hands-on experience in designing smart systems using ESP32, relay modules, DHT sensors, LCD displays, and cooling components. It also demonstrates how modern smart devices can be developed for home automation and environmental monitoring applications.

Fig 1.1 Iot Based Smart Cooler

The IoT Based Smart Cooler project works by continuously monitoring the surrounding environmental conditions and automatically controlling the cooling system using the ESP32 microcontroller. The system mainly consists of an ESP32 board, DHT11 temperature an humidity sensor, relay module, cooling unit, LCD display, and IoT connectivity features. The integration of these components enables automatic cooling control and real-time monitoring. The DHT11 sensor continuously measures the temperature and humidity of the environment and sends the data to the ESP32 microcontroller. The ESP32 processes the sensor readings and compares them with the predefined temperature limits programmed in the system. When the temperature rises above the set limit, the ESP32 activates the relay module, which turns on the cooling device such as a fan or Peltier cooling module. When the temperature decreases below the required level, the relay automatically switches off the cooling system to save energy. The LCD display connected through the I2C interface shows real-time temperature, humidity, and system status information. This allows users to monitor the environmental conditions directly from the display unit. The ESP32 also provides wireless connectivity using Wi-Fi, enabling the system to communicate with a web server or IoT platform for remote monitoring and control.

Through the IoT interface, users can monitor the cooler status, sensor readings, and control operations remotely using a mobile phone or computer. The project demonstrates automation, intelligent decision-making, and remote access features, making the cooling system more efficient, reliable, and user-friendly.

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II. Review of Literature

IoT-based cooling systems have received attention because of their ability to combine environmental sensing with automated control and remote monitoring. Traditional cooling systems generally depend on manual operation, whereas IoT-enabled systems can respond automatically to changing environmental conditions.

Sharmila and Bhuvaneswari proposed an IoT-enabled smart cooling system for a server room using a DS18B20 temperature sensor and Raspberry Pi controller. According to the supplied source, the proposed system demonstrated improved accuracy compared with existing work.

Roy and Banerjee presented a wireless IoT-based system using an ESP32 microcontroller to monitor and manage cooler parameters, including temperature and water level, in real time. Their work focused on energy efficiency and automated maintenance of smart cooling units.

The reviewed work indicates that sensor-based monitoring, microcontroller control, and wireless communication are important components of intelligent cooling systems. The ESP32 is particularly useful for IoT applications because it combines processing capability with built-in wireless communication. The supplied project similarly integrates ESP32, DHT11, relay, LCD and cooling components for automated cooling and real-time monitoring.

However, a practical smart cooler should not only sense environmental conditions but also provide automatic decision-making, local status information, and remote accessibility. The proposed system addresses these requirements through a combined hardware and software architecture.

III. Problem identification

Conventional air coolers have several limitations:

- Manual switching and control increase user effort.
- Continuous operation can lead to unnecessary power consumption.
- Users may not be able to monitor temperature and humidity continuously.
- Conventional coolers generally provide limited remote-control functionality.
- Low water-level conditions may not be detected automatically.
- Maintenance requirements may not be communicated to the user.
- The cooling operation may not adapt automatically to changing environmental conditions.

The supplied project identifies the need for an intelligent and energy-efficient cooling system that can automatically monitor environmental conditions and control the cooling mechanism.

Therefore, the main research problem is:

How can an ordinary cooling system be converted into an intelligent, automated and remotely accessible system that provides temperature-based control while reducing unnecessary energy consumption?

IV. Solution

The proposed solution is an IoT-based smart cooler controlled by an ESP32 microcontroller. The system continuously obtains temperature and humidity information from a DHT11 sensor. The ESP32 compares the measured temperature with a predefined threshold.

When the temperature rises above the specified threshold, the controller activates the relay and starts the cooling unit. When the temperature falls below the required level, the controller switches the cooling unit off. This automatic control avoids continuous operation when cooling is not required.

The basic solution consists of:

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1. **ESP32 microcontroller** – processes sensor information and controls the system.
2. **DHT11 sensor** – measures temperature and humidity.
3. **Relay module** – provides switching control for the cooling unit.
4. **Cooling unit** – performs the actual cooling operation.
5. **LCD display** – displays temperature, humidity and system status.
6. **Wi-Fi/IoT interface** – enables remote monitoring and control.
7. **Water-level sensing/alert mechanism** – supports monitoring of water availability where implemented.

The source describes the same operating principle: the DHT11 sends environmental readings to the ESP32, which compares the readings with programmed limits and activates or deactivates the cooling device through a relay.

V. Proposed Methodology

The proposed methodology consists of four major stages:

5.1 Hardware Design

The ESP32 acts as the central controller. The DHT11 sensor is connected to the ESP32 for measuring temperature and humidity. A relay module is connected to the controller to switch the cooling device. An LCD display provides local information to the user.

The system can also incorporate a water-level sensor to detect the availability of water in the cooler. The ESP32 communicates with an IoT platform or web interface through Wi-Fi.

5.2 Sensor Data Acquisition

The DHT11 continuously measures:

- Ambient temperature
- Relative humidity

The sensor data is transferred to the ESP32. The controller processes the readings and determines the required cooling action.

5.3 Automatic Cooling Control

A predefined temperature threshold is programmed into the ESP32. The control logic is:

- If the measured temperature is higher than the threshold → cooling ON.
- If the measured temperature reaches or falls below the required level → cooling OFF.
- If the water level is insufficient → generate an alert and prevent inappropriate operation where the hardware design supports this function.

This approach allows the cooling unit to operate according to environmental requirements instead of remaining continuously switched on.

5.4 IoT Communication

The ESP32 uses Wi-Fi connectivity to communicate with a remote IoT interface. The user can observe temperature, humidity, cooler status and other available parameters remotely. Remote control can also be implemented through the IoT interface.

The source specifically states that the ESP32 provides Wi-Fi communication with a web server or IoT platform and allows monitoring and control through a mobile phone or computer.

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Algorithm

Step 1: START

Step 2: Initialize ESP32, DHT11 sensor, LCD and relay.

Step 3: Initialize Wi-Fi and IoT communication.

Step 4: Read temperature and humidity from the DHT11 sensor.

Step 5: Check whether valid sensor data has been received.

Step 6: Display temperature, humidity and cooler status on the LCD.

Step 7: Compare measured temperature with the predefined threshold.

Step 8: If temperature is above the threshold, activate the relay and switch ON the cooling unit.

Step 9: If temperature is at or below the required level, deactivate the relay and switch OFF the cooling unit.

Step 10: Check water-level status if a water-level sensor is installed.

Step 11: Generate an alert when the water level is low or maintenance is required.

Step 12: Send sensor readings and cooler status to the IoT platform.

Step 13: Receive remote-control commands, if provided by the user.

Step 14: Update the cooler operating state.

Step 15: Repeat the monitoring process continuously.

Step 16: STOP.

System Flow

DHT11 Sensor → ESP32 → Data Processing → Threshold Comparison → Relay → Cooling Unit

At the same time:

ESP32 → LCD Display

and

ESP32 → Wi-Fi → IoT Platform → Mobile/Web Interface

VI. RESULT

The supplied project reports successful implementation and testing of the IoT-based smart cooler, including automatic temperature regulation, remote accessibility and efficient power management.

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During operation, the DHT11 sensor provides real-time environmental measurements to the ESP32. The controller processes these measurements and automatically changes the operating state of the cooling unit according to the programmed temperature conditions. The LCD provides local visualization of temperature, humidity and system status.

The IoT connectivity provides an additional layer of accessibility by allowing the user to monitor the cooler remotely through a mobile device or computer. This reduces dependence on manual operation and improves convenience.

The major observed functional outcomes are:

Parameter	**Observed System Function**
Temperature monitoring	Real-time measurement using DHT11
Humidity monitoring	Real-time measurement using DHT11
Automatic cooling	Controlled using ESP32 and relay
Local display	Temperature, humidity and status displayed on LCD
Remote monitoring	Enabled through Wi-Fi/IoT connectivity
Remote control	Supported through IoT interface
Energy management	Cooling operates according to programmed conditions
Water-level monitoring	Alert functionality supported where sensor is implemented

The supplied source does not provide numerical temperature-control accuracy, energy-consumption percentages, response time measurements, or comparative experimental datasets for the smart cooler. Therefore, such numerical values have not been fabricated in this paper.

VII. Conclusion

This research presents the design and implementation of an IoT-based smart cooler using an ESP32 microcontroller, DHT11 temperature and humidity sensor, relay module, LCD display, cooling unit and wireless connectivity. The system combines sensing, automatic decision-making and remote monitoring to improve the functionality of a conventional cooler.

The proposed system continuously monitors environmental conditions and automatically controls the cooling mechanism based on predefined temperature limits. This reduces manual intervention and can help avoid unnecessary operation of the cooling unit. The LCD provides convenient local monitoring, while Wi-Fi and IoT connectivity allow users to access the system remotely.

The source project confirms successful automatic temperature regulation, remote accessibility and efficient power-management functionality. Overall, the proposed smart cooler provides a practical, low-cost and scalable approach for incorporating IoT technology into everyday cooling appliances.

VIII. FUTURE SCOPE

The proposed smart cooler can be further improved in several ways:

1. **AI-Based Temperature Prediction:** Machine-learning techniques can be incorporated to predict cooling requirements from historical temperature and humidity data.
2. **Advanced Energy Management:** Variable-speed fan control can be introduced instead of simple ON/OFF control to achieve finer cooling and energy management.
3. **Mobile Application:** A dedicated mobile application can provide real-time temperature graphs, cooler status, notifications and remote-control functions.
4. **Cloud Data Storage:** Sensor readings can be stored in the cloud for long-term analysis and performance monitoring.
5. **Improved Water-Level Monitoring:** A more accurate water-level sensor can provide continuous measurement and automatic low-water alerts.
6. **Voice Control:** Voice assistants can be integrated to allow users to operate the cooler using voice commands.

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7. **Predictive Maintenance:** Sensor and operational data can be analysed to identify abnormal behaviour and provide maintenance alerts.
8. **Solar-Powered Operation:** Solar panels and battery storage can be integrated to reduce dependence on conventional electrical power.
9. **Smart Home Integration:** The cooler can be integrated with broader home-automation platforms so that cooling operation can respond to occupancy, ambient conditions and other smart appliances.
10. **Enhanced Sensors:** More accurate temperature, humidity, air-quality and water-level sensors can be incorporated to improve system reliability.

IX. REFERENCES

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[3] Sachin Malviya, Ramu Pal, Ravi Arya, Rahul Singh, Ayush Verma, Nikhil Patel and Devendra Mehra, "Design and Implementation of an IoT Based Smart Cooler," International Journal of Recent Technology Science & Management (IJRTSM), Vol. 10, No. 4, April 2025. The supplied source identifies the paper as an IoT-based smart cooler using ESP32 and related sensor/control components.