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Enhancing Power Efficiency in Meeting Rooms of Commercial Buildings Using Smart IoT Devices

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Abstract- Inefficient manual control of Air Conditioning (AC) units is a significant source of energy waste in meeting rooms, particularly in commercial buildings. To address this issue, we propose a cost-effective solution using the M5StickC IoT development kit, equipped with an Infrared (IR) emitter and a Real-Time Clock (RTC) for automating AC operation. This system eliminates the need for manual intervention by synchronizing with Google Calendar to detect scheduled meeting times, automatically turning the AC on before meetings and off afterward. Further enhancing energy efficiency, a Passive Infrared (PIR) sensor monitors human presence near the AC unit, allowing it to deactivate during periods of inactivity. Additionally, a simple web service is developed which enables users to easily track room occupancy and AC status remotely. Tested with a Gree AC unit in a meeting room, the solution achieved significant energy savings, demonstrating its potential as a highly effective and economical approach to reducing electricity consumption.

Keywords- *power efficiency, IoT devices, energy saving.*

I. INTRODUCTION

Internet of Things (IoT) and Artificial intelligence (AI) driven energy management in commercial buildings are emphasized for their role in reducing costs and promoting sustainability [1-2]. These systems are part of broader efforts to achieve energy efficiency goals and meet sustainability targets, which are increasingly important for businesses looking to reduce their power waste [3-4].

Recent studies, such as the deployment of IoT networks in smart buildings, demonstrate how real-time monitoring of room usage allows for predictive control strategies that minimize energy waste [5-6]. This approach helps align energy consumption with actual room usage patterns, optimizing systems like air conditioning, lighting, and heating to reduce power waste. AI models can further enhance this by predicting occupancy trends and adjusting energy use accordingly [7-8].

Meeting rooms, which are commonly found in business and commercial spaces, are typically equipped with lighting and AC systems. However, significant energy is often wasted when these systems are left running in unoccupied rooms or after meetings, mainly due to reliance on manual switching systems. This inefficiency results in unnecessary energy consumption. Given that AC units account for a substantial share of energy use [9-10], this work proposes a cost-effective, intelligent energy-saving solution that automatically manages AC power, switching units on and off based on meeting schedules to minimize waste.

The system leverages an IoT device for real-time monitoring of meeting times. As a scheduled meeting approaches, the device sends a signal to power on the AC unit for the meeting's duration. Once the meeting concludes, unless another meeting is scheduled immediately after, the IoT device issues a power-off command to deactivate the AC. The system can also be extended to manage lighting.

To further enhance energy efficiency, particularly in larger meeting rooms with multiple AC units and low occupancy, a Passive Infrared (PIR) [11] motion detector is integrated into the IoT system. This sensor detects movement, and if no motion is detected, it sends a power-off command to the AC unit, even during a scheduled meeting.

The proposed solution is both cost-effective and compatible with a wide range of AC manufacturers, including popular brands like Midea, Sharp, and Gree, making it suitable for various applications.

II. PROPOSED SOLUTION

The proposed solution addresses the issue of energy waste from AC units in meeting rooms within commercial buildings. HVAC systems typically account for 44% of the total energy bill, whereas lighting only contributes 9% [12]. With the adoption of new technologies, such as cost-saving LED lighting [13], the focus of the proposed design shifts primarily toward improving the energy efficiency of AC usage. However, the system remains adaptable to include lighting management as well.

This compact and straightforward system utilizes an M5StickC IoT device [14] connected to a PIR HAT sensor. The IoT device is powered via a USB-C cable, as illustrated in Figure (1), and is programmed using the Arduino IDE software [15].

Figure (1): Solution Setup: M5StickC IoT device with PIR Hat

The solution is highly cost-effective, requiring only a one-time investment of $20. This minimal expense is easily justified by the significant long-term savings on electricity bills. The simple design, combined with the low

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implementation cost, makes it a practical and affordable solution for reducing energy consumption in meeting rooms.

A. M5stickC IoT Development Kit

The M5StickC is a compact IoT device built on the ESP32 board, designed for portability and ease of use. As shown in Figure (2), this open-source development board is equipped with a variety of hardware features that enhance its functionality. Key components include a 3-axis accelerometer, 3-axis gyroscope, red LED, infrared transmitter, real-time clock (RTC), microphone, two buttons, a 0.96-inch LCD display, and a power/reset button.

Its portability is ensured by a 95mAh lithium battery, allowing for convenient operation on the go. The M5StickC also includes expansion interfaces, enabling compatibility with a wide range of modules and accessories, offering increased customization and versatility. It supports multiple development platforms, such as UIFlow, MicroPython, Arduino, and the .NET nanoFramework, giving developers flexibility in implementation.

Figure (2): M5StickC IoT device

B. PIR HAT Motion Sensor

The PIR HAT [16] is a human body infrared sensor specifically designed for compatibility with the M5StickC as shown in Figure (3). As a passive infrared detector, it detects infrared radiation emitted or reflected by humans or objects nearby. When it senses this radiation, the sensor generates a high-level signal and initiates a delay period during which it maintains the high signal level, enabling repeated triggering until the signal returns to low.

This sensor offers a practical solution for detecting human presence or movement across various applications, such as security systems, occupancy sensing, automation, and other projects requiring activity monitoring. By capturing fluctuations in infrared radiation patterns, the PIR HAT can trigger specific actions, such as turning on lights, activating alarms, or initiating automated processes.

Its passive design means it does not emit radiation but relies on detecting changes in ambient infrared radiation, making it an energy-efficient and reliable choice for presence detection. This capability makes the PIR HAT an ideal component for this project. Integrating the M5Stack AS312 PIR sensor into the system significantly enhances its ability to respond to environmental movement, improving both the efficiency and functionality of the overall solution.

the user. This feature improves user tracking and ensures transparency throughout the synchronization process.

Figure (4): M5StickC LCD after time synchronization through NTP server

1. Web Service

To simplify meeting room availability checks and monitor AC usage, a web page has been developed and deployed on the M5StickC IoT device, which acts as a web server to handle user requests. The web page, as shown in Figure (5), is divided into two sections.

The first section displays the current room availability and AC status. The room status, synchronized with Google Calendar, indicates whether the room is "available" or "busy." The AC status shows whether the unit is on or off and provides detailed information about its operating mode (cool, dry, or heat). The second section offers users the ability to remotely control the AC unit, allowing them to turn it on or off from a distance. This user-friendly interface makes it easy to monitor room status and adjust AC settings remotely, improving convenience and operational efficiency.

2. Synchronization of Google Calendar with the IoT Device

The primary function of the code is to synchronize Google Calendar with the IoT device using its Wi-Fi connection to access the internet. This synchronization is achieved by retrieving events via the iCal feed from Google Calendar, which automatically pulls in the day's event times. Each calendar can be synchronized independently, allowing the IoT device to fetch real-time updates. Google Calendar also supports syncing with other platforms, such as Outlook or Apple Calendar, or it can be used in a read-only format.

To manage meeting schedules, you can create a free Google account and input daily events into the Google Calendar. By enabling public sharing in iCal format, as shown in Figure (6), a public URL is generated. This URL allows the IoT device to automatically fetch and sync the daily event schedule. The synchronization ensures that any updates—such as new events or deletions—are instantly reflected on the IoT device.

Once synchronized, the IoT device retrieves the current RTC time and compares it with the scheduled meeting times. If it matches a meeting time, the AC control function is activated, sending an IR signal to turn on the AC. After the meeting ends, the IoT device sends another IR signal to turn off the AC. This process is repeated for each scheduled meeting throughout the day.

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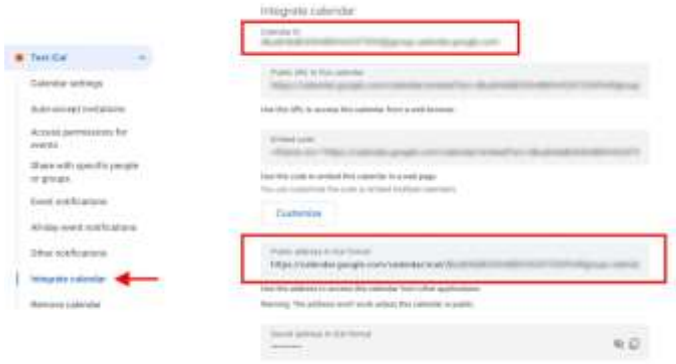

Figure (6): Google Calendar (Free Account) with iCal Format Sharing

1. AC Control Function

Once synchronization with Google Calendar is complete and the meeting time approaches, the AC control function is activated. This function is designed to emulate an infrared remote controller, utilizing the Arduino IDE and the M5StickC's built-in IR emitter. Positioned near the AC unit, the module manages the AC remotely using the Arduino-heatpumpir library [18] to generate infrared signals. While there are various libraries available for this purpose, the selected one stands out by supporting a wide range of AC manufacturers through uniform code instructions.

The code is adaptable, accommodating multiple modes, including heat, cool, and dry, as well as allowing for temperature configuration, power on/off, and fan speed adjustments. This function is invoked at each meeting time to seamlessly turn the AC unit on or off.

By integrating all of these functions into a single code structure, the system effectively monitors and controls AC usage in meeting rooms. This automation reduces the reliance on manual controls, minimizing human intervention and resulting in significant power savings.

III. EXPERIMENTAL SET-UP

The designed system was deployed and tested in executive meeting room in business building equipped with Gree AC unit as shown in Figure (7). Given the compact design of the M5StickC IoT device and its enclosure, the module was affixed close to the AC unit using a bi-adhesive tape, as illustrated in Figure (8).

Once the system is set up, the RTC time is synchronized through the NTP server as discussed previously. A free Google account has been created for the meeting room and all daily meetings and events are updated on this account and synced to the IoT device using ICal protocol as shown in Figure (9) . Subsequently, the RTC time is compared with the daily events of the Google Calendar time, and when the meeting time arrives, the AC unit is powered up and for better tracking the IoT embedded led is flashed during the meeting time as indictor of the room occupancy as shown in Figure (10). Simultaneously, the M5StickC LCD displays a message listing all daily events times as illustrated in Figure (11). Following eliminates the necessity for manual switching ON/OFF of AC units, offering an automated solution that mitigates electricity wastage. This system is particularly advantageous in larger meeting rooms featuring numerous AC units, where its seamless operation contributes to substantial energy savings.

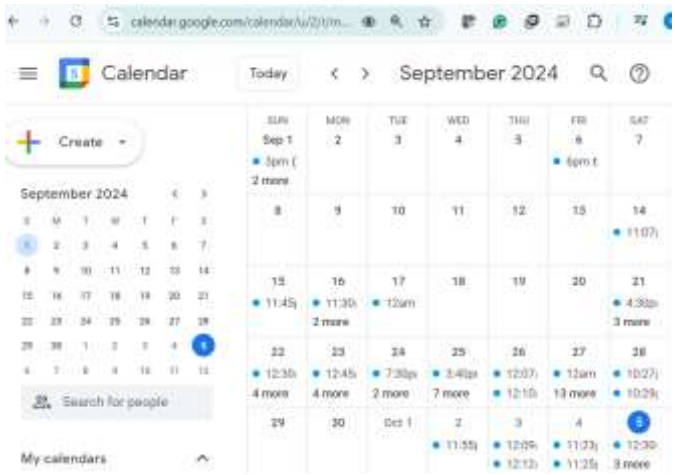

Figure (9): Google Calendar of the Meeting Room with All Listed Events

Figure (10): AC Automatically Powered On During the Meeting, Indicated by Flashing LED

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Figure (11): All-Day Events Synced and Displayed on the IoT LCD

IV. CONCLUSIONS

A solution offers efficient and automated control of AC units in meeting rooms is proposed. It was tested in an executive meeting room equipped with a Gree AC unit. The system utilizes the M5StickC IoT device, which features a built-in IR transmitter and RTC module. By connecting to the internet via the existing Wi-Fi network and integrating with a free Google Calendar account, the solution effectively manages the meeting room's schedule.

The system accurately synchronizes with real-time events, automatically activating the AC unit during meetings and deactivating it afterward, unless another meeting is scheduled immediately after. This eliminates the need for manual control. Additionally, the system incorporates a motion detection feature, which promptly turns off the AC unit when no individuals or objects are detected nearby.

Overall, the system provides a practical, cost-effective, and user-friendly approach to AC management. Its implementation has the potential to significantly reduce energy waste, aligning with the growing emphasis on sustainable and energy-efficient solutions.

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