IOT-BASED SMART CLASSROOM AUTOMATION SYSTEM

Aman Raikwar[1], Manish Sharma[2], Rishabh Sahu[3], Umesh Ahirwar[4], Umesh Jaiswal[5*], Meha Shrivastava[6]

[1,2,3,4,5]Under Graduate Student, [6]Assistant Professor, Department of Electronics and Communication Engineering, Sagar Institute of Science and Technology, Bhopal, Madhya Pradesh, India

*Corresponding Author: umeshjaiswal102003@gmail.com

ABSTRACT

This paper presents an IoT-based smart classroom automation system that enables real-time monitoring and control of electrical appliances such as lights and fans through a custom-built web interface. The system is powered by a centralized microcontroller (NodeMCU/ESP8266/ESP32) connected to a Wi-Fi network, acting as a communication bridge between user commands and classroom devices. Users can access the system via any internet-enabled device, including smartphones, tablets, or computers, to control a wide range of appliances remotely via web interface. The platform supports personalized automation scenarios based on specific schedules or events, improving energy efficiency, convenience, and classroom comfort. Robust encryption protocols ensure data privacy, while over-the-air updates keep the system secure and feature-rich. By integrating conventional appliances into a unified, web-controlled network, the proposed system enhances hygiene, accessibility, and automation in modern learning environments, offering a smart, user-friendly solution for classroom management.

Keywords: Internet of Things (IoT), Smart Classroom, ESP32, Web Interface.

1. INTRODUCTION

IoT-based Smart Classroom Automation System aimed at transforming traditional classrooms into intelligent, energy-efficient, and interactive learning environments. The system utilizes a Wi-Fi-enabled microcontroller (NodeMCU/ESP8266/ESP32) as a centralized hub to manage and control classroom devices such as lights, fans, air conditioners, and projectors through a web-based interface accessible from smartphones, tablets, or computers. Key features include smart lighting automation based on occupancy, user preferences, and schedules, enhancing both energy efficiency and user comfort. Integrated climate control allows dynamic management of temperature and humidity via smart thermostats and sensors, ensuring a balanced indoor environment. The system also supports personalized automation routines, voice control, and real-time monitoring, with data logging for informed decision-making.

1.1 IOT APPLICATION IN CLASSROOM AUTOMATION

The integration of Internet of Things (IoT) technology into classroom automation has ushered in a new era of intelligent and interconnected living spaces. With a myriad of applications, IOT is transforming traditional homes into smart, responsive environments that offer increased convenience, energy efficiency, and security. Here's an exploration of some key IOT applications in classroom automation:

1.1.1 Smart Lighting Systems: IOT-enabled smart lighting systems allow owners to web interface control and automate their lighting fixtures. Whether adjusting brightness, setting schedules, or changing colour temperatures, users can personalize their lighting preferences through web page. Motion sensors further enhance energy efficiency by automatically turning off lights in unoccupied rooms.

1.1.2 Thermostats and Climate Control: Smart thermostats equipped with IOT capabilities enable precise control of heating, ventilation, and air conditioning (HVAC) systems. Users can remotely adjust temperatures, create schedules, and receive insights into energy consumption. IOT technology allows for adaptive learning, where the thermostat learns from user behavior and optimizes climate control for comfort and efficiency.

1.1.3 Security and Surveillance: Classroom security is greatly enhanced through IOT applications. Smart cameras, doorbell cameras, and motion sensors provide real-time monitoring and alerts. These devices can be accessed remotely, enabling homeowners to check on their property and receive notifications for unusual activities. Smart locks with IOT integration allow for secure, remote access control.

1.1.4. Home Appliances Automation: IOT-enabled home appliances, such as refrigerators, fans, and coolers.ovens, and washing machines, bring automation and convenience to daily tasks. Users can receive notifications about appliance status, control settings remotely, and even automate tasks based on preferences or time of day. For instance, a smart oven can be preheated remotely before arriving home.

1.1.5 Energy Management and Monitoring

IOT technology facilitates real-time monitoring and analysis of energy consumption. Smart meters and sensors provide insights into usage patterns, helping owners make informed decisions to reduce energy waste and lower utility costs. Automated energy-saving routines can be programmed based on occupancy and preferences.

2. LITERATURE REVIEW

The advancement of Internet of Things (IoT) technology has led to significant innovations in smart automation systems, particularly in the domains of home and educational automation. Various studies have explored the use of IoT in creating intelligent environments that enhance user convenience, operational efficiency, and resource managements.

In [1], Satyendra K. Vishwakarma et al. developed a home automation system using Raspberry Pi and sensors to monitor and control household appliances. The system provided a web-based interface for remote operation and emphasized energy efficiency and user comfort. Although effective, the solution was limited in scalability and primarily focused on residential environment.

An IoT-based smart classroom framework was introduced in [2], where Shardha Somani et al. implemented sensor nodes and actuators to control lighting and fans based on occupancy and ambient conditions. The system demonstrated improved energy efficiency and a better classroom environment. However, the lack of a centralized user interface and limited real-time feedback restricted its practical usability.

In [3], a classroom automation system was proposed using Arduino and Bluetooth communication. The project focused on wireless control of lights and fans through a mobile application. While this system showcased cost-effectiveness and simplicity, it lacked cloud connectivity and broader IoT integration, limiting remote access and scalability.

The study in [4] presented an IoT-enabled smart learning environment where devices could be controlled using voice commands and gestures. The implementation involved cloud-based services and artificial intelligence for better user interaction. Although innovative, the solution involved high computational requirements and was not feasible for budget-constrained institutions.

Another relevant work is in [5], where NodeMCU/*ESP32* (ESP8266) was used to implement a smart classroom system with real-time data monitoring and appliance control. This approach provided a solid foundation for scalable and interactive classroom automation. From the analysis of existing literature, it is evident that while multiple IoT-based solutions exist for home and classroom automation, many of them either lack real-time web control, centralized automation features, or seamless scalability. There is a need for an integrated, secure, and user-friendly system that can be easily deployed in educational environments and controlled through a universal interface.

The proposed system in this paper builds upon the strengths of these previous studies while addressing their limitations. It aims to develop a scalable, web-controlled smart classroom automation system using ESP32/ESP8266, offering features like real-time monitoring, personalized automation routines, and enhanced energy efficiency, all accessible through a custom web interface.

3.PROBLEM STATEMENT:

In Traditional classroom environments relay heavily on manual control of electrical devices such as lights, fans, projectors, and air conditioners, leading to inefficiencies, increased energy consumption, and reduced productivity. The absence of integration among these devices limits centralized control, making it challenging for educators and administrators to manage classroom conditions efficiently.

There is a growing need for an IoT-based smart classroom automation solution that integrates seamlessly with existing infrastructure. Such a system should offer centralized control, real-time monitoring, and intelligent automation to enhance comfort, energy efficiency, and overall learning experience.

3.1 Enhance Comfort and Convenience: Provide personalized and automated experiences tailored to the preferences and routines of homeowners. This may involve scheduling routines, adjusting settings based on occupancy or environmental conditions, and integrating voice or gesture-based control mechanisms for hands-free operation

3.2 Streamline Device Control: Enable centralized and remote control of classroom appliances—such as lighting, fans, projectors, and HVAC systems—through an intuitive web-based interface. This would simplify operations and reduce the dependency on manual intervention, allowing teachers to focus more on instruction and less on environment management.

3.3 Optimize Energy Efficiency : Implement intelligent energy management strategies to reduce waste and lower utility costs. This includes monitoring energy consumption, identifying inefficiencies, and automating energy-saving actions such as adjusting thermostat settings, managing lighting levels, and optimizing appliance usage.

3.4 Streamline Device Control: Enable centralized and remote control of classroom appliances—such as lighting, fans, projectors, and HVAC systems—through an intuitive web-based interface. This would simplify operations and reduce the dependency on manual intervention, allowing teachers to focus more on instruction and less on environment management.

3.5 Improve Accessibility and Monitoring: Through real-time web interfaces accessible via smartphones, tablets, or PCs, authorized users can monitor device status and usage history. This supports better maintenance planning and data-driven decisions for energy and resource optimization.

4. PROPOSED METHODOLOGY

To address the limitations of traditional classroom appliance control and enhance convenience, energy efficiency, and remote accessibility, a compact IoT-based automation device is proposed for seamless integration into existing electrical wall boards commonly found in classrooms. The device enables both manual operation through traditional wall switches and remote control through smart interfaces.

The system integrates Wi-Fi-enabled microcontrollers, specifically the ESP32 or ESP8266, capable of hosting web servers and handling real-time control signals. A simple web page is hosted on either the microcontroller or a local network server. Users access the control interface by connecting to the IP address of the ESP32 via a web browser. Upon interaction with the interface, such as pressing a button to operate a light, a request is sent to the microcontroller. The command is processed, and the corresponding relay is activated to switch the appliance on or off.

Relays function as digital switches and are connected to various classroom appliances including fans, lights, and projectors. Control signals are transmitted via the internet to the ESP32, which manages the activation of the relays. The system supports both manual switch operation and automated control, enabling appliance management from any location with internet connectivity. In addition to web-based control, the system is compatible with mobile applications and voice assistants such as Google Home, allowing for enhanced user interaction.

Sensor data and system status can be monitored through a secure web portal, facilitating real-time decision-making and automation. This dual-functionality system retains traditional switch usage while offering smart automation capabilities, forming a bridge between legacy infrastructure and modern IoT applications in educational environments.

5. BLOCK DIAGRAM

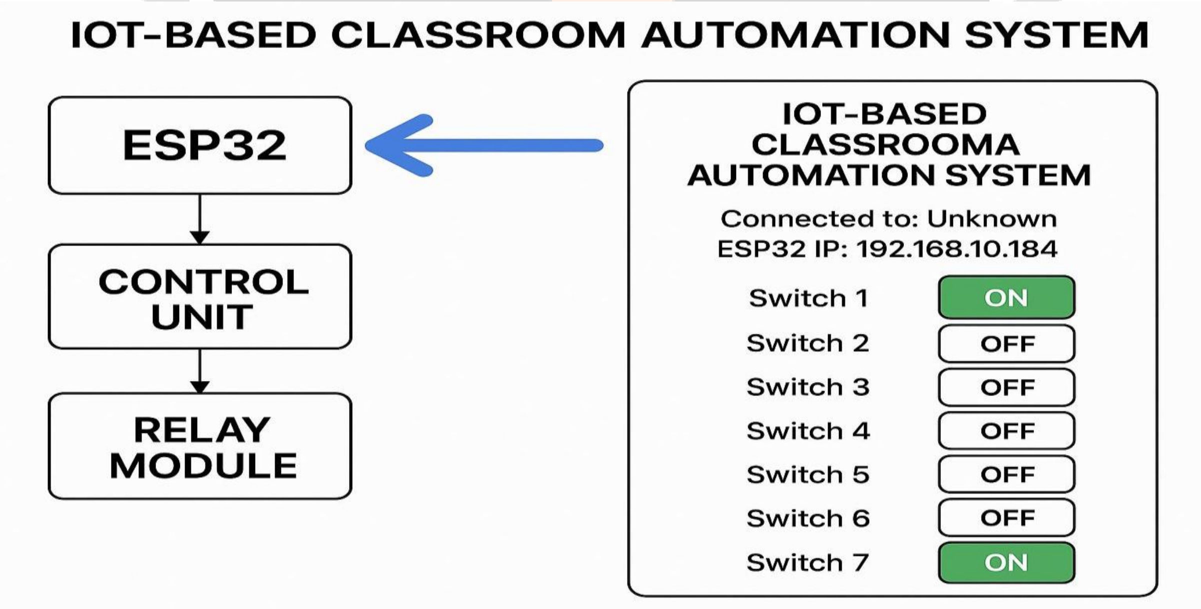

Fig-1: Block diagram

In this diagram:

1. Switch on the device - User Accesses Web Interface, The user opens a browser and visits the IP address of the ESP32 (192.168.10.184).
2. The web page shows buttons labled Switch 1–8, each controlling a different appliance (e.g. fan, light).
3. Command Sent via Web Page- When the user clicks a button ("ON" for Switch), a HTTP request is sent to the ESP32. ESP32 receives the request from the web page.
4. Relay Module- The relay module acts like an electronic switch . Each relay corresponds to one of the switches on the web page.
5. Based on the relay's state, the connected appliance (fan, light, etc.) turns ON or OFF. The web page may reflect this change with a visual update (button changing color/status).

Web Interface → ESP32 (Web Server) → Control Unit → Relay Module → Appliances (Fan/Light)

6. EXPERIMENTAL SETUP

6.1 HARDWARE

Node MCU: is an open-source firmware and development board that allows for easy and rapid prototyping of Internet of Things (IOT) devices. It is based on the ESP8266 microcontroller, which is a low-cost Wi-Fi chip with a full TCP/IP stack and microcontroller capabilities. Node MCU includes a lightweight, high-level scripting language interpreter, which allows for easy programming of the device using the scripting language.

Relay module: Relay modules are fundamental components in home automation systems, acting as electromechanical switches that allow for the control of high-power devices through low-power electronic signals. These modules play a crucial role in automating various household appliances, providing a bridge between digital control systems and physical devices.

Electronic Button: A button is a simple electrical switch that is typically used to control a circuit.

Led: An LED, or Light Emitting Diode, is a semiconductor device that emits light when current flows through it. LEDs are commonly used in various applications, including lighting, displays, indicators, and backlighting.

6.2 SOFTWARE

Arduino IDE: The Arduino Integrated Development Environment (IDE) is essential for writing, compiling, and uploading code to the Arduino Uno.

Web Server: The NodeMCU runs a lightweight web server that hosts the control interface. It listens for HTTP requests and triggers actions like switching lights or fans.

KiCad: stands as a robust, open-source Electronic Design Automation (EDA) suite, empowering engineers, hobbyists, and students to conceptualize, design, and fabricate printed circuit boards (PCBs) with precision and efficiency.

HTML/CSS/JavaScript: These languages create the web-based user interface displayed in the browser. HTML structures the content, CSS styles it, and JavaScript handles button interactions**.**

7. WORKING

Mobile Application Integration (Web Page): The home automation system is integrated with the web interface platform, allowing users to control and monitor their home appliances remotely via a dedicated mobile application. Web page provides an intuitive interface for device management, scheduling, and customization of automation routines, accessible from smartphones Node MCU Integration: The Node MCU serves as the central hub of the classroom automation system, facilitating Wi-Fi connectivity and communication with connected devices.

It hosts the firmware responsible for processing commands received from the web interface, manual switches.

Relay Module Control: The relay module acts as a switch for controlling switch-controllable class appliances, such as lights, fans, and electronic devices. The Node MCU controls the relay module to turn appliances on/off based on user commands received via the Web Interface, manual switches. LED Feedback: LED indicators provide visual feedback on the status of connected devices and the system's operation. LEDs may indicate whether a device is powered on/off, whether commands are being processed, or if there are any errors or alerts.Power Adapter: The power adapter supplies the necessary voltage and current to power the Node MCU, relay module and other components of the classroom automation system. It ensures stable and reliable operation of the system by providing consistent power supply. In summary, the classroom automation project integrates various control mechanisms, including mobile application control via the web interface, manual switches to provide a versatile and user-friendly interface for managing and automating home appliances and devices.

The key components, including Node MCU, relay module, LEDs, and power adapter, work together seamlessly with the Web interface platform to enable efficient communication, control, and automation of the class environment.

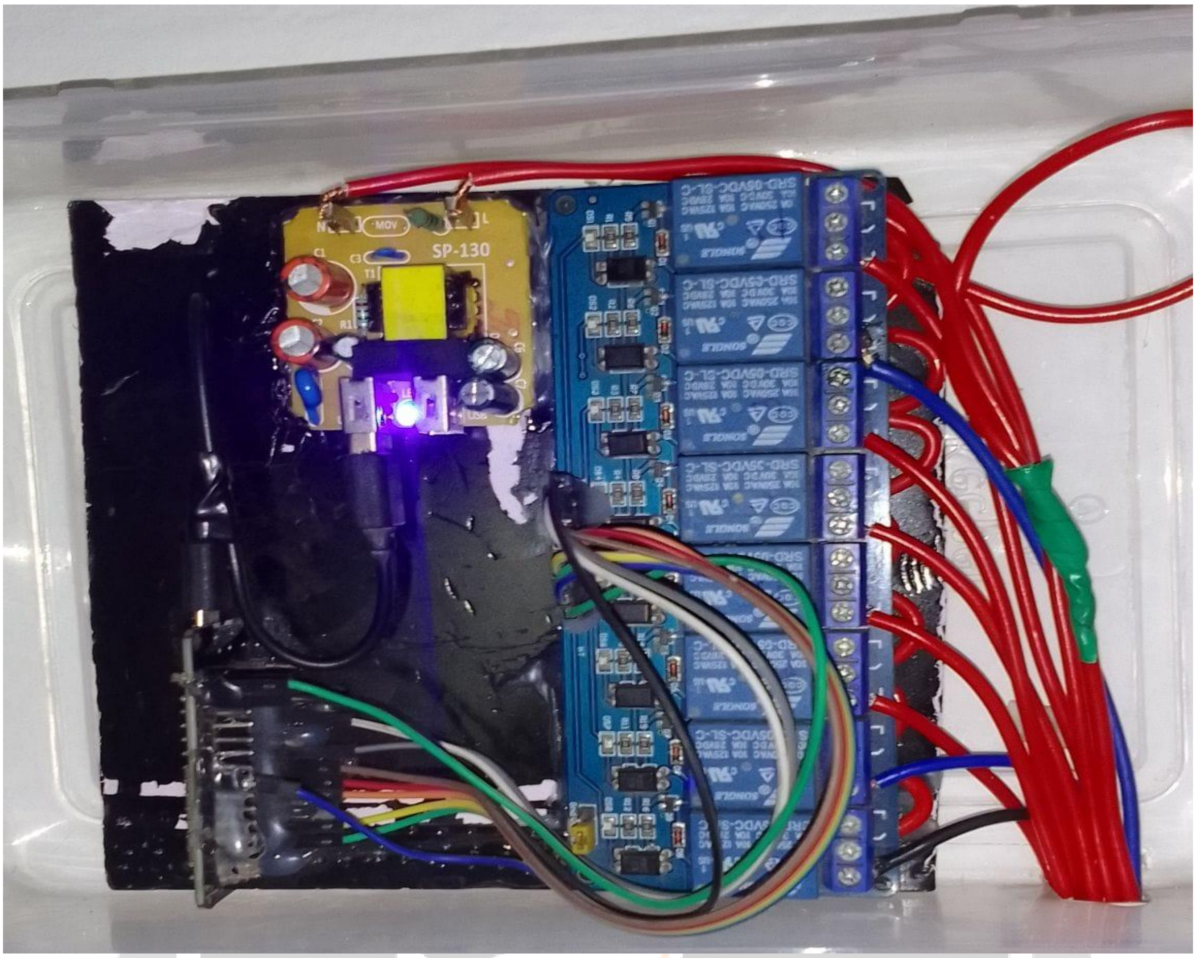

Fig-2: Real time Diagram

8. RESULTS:

The proposed IoT-based smart classroom automation system was successfully implemented and tested in a simulated classroom environment. The system demonstrated effective performance in real-time control and monitoring of various classroom appliances through a custom-built web page interface. The results validate the feasibility, efficiency, and usability of the solution in educational settings. The system retained compatibility with physical wall switches. Appliances could be operated both manually and via the web interface without conflict. The system accurately synchronized the status of each device, reflecting real-time updates on the web dashboard even when manual switches were used. Testing confirmed that the system could be accessed remotely within the same network, and with port forwarding or dynamic DNS configuration, access over the internet was also achieved securely. Multiple users were able to interact with the system simultaneously, with no noticeable delay or malfunction.

9. CONCLUSION:

This paper presented a practical implementation of a web-controlled IoT-based smart classroom automation system. With real-time control and monitoring capabilities, the proposed solution enhances educational infrastructure through technology. Future work may include voice control integration, AI-based occupancy detection, and expanded device support. successful development and implementation of an IoT-based smart classroom automation system that is controlled via a web interface. The system allows users to remotely monitor and control classroom devices such as lights, fans in real-time, leading to improved energy efficiency and user convenience. It demonstrates how IoT and web technologies can be integrated to create a smart, sustainable, and easily manageable classroom environment. The system’s modular and scalable design makes it adaptable for wider use in multiple classrooms or institutions. Moreover, its user-friendly interface ensures accessibility even for non-technical users. Future enhancements could include AI-based automation, voice control, and mobile app integration to make the system even more intelligent and interactive.

10. FUTURE SCOPE:

Integration with Advanced Sensors- Future versions of the system can incorporate a wider range of smart sensors such as motion detectors, CO_2 sensors, ambient light sensors, and presence detectors.
Enhanced Security Features- An IoT systems are prone to cybersecurity risks, future implementations can focus on enhancing data security.
Mobile App Development- Although the current system operates via a web-based interface, a dedicated mobile application can be developed for Android and iOS platforms

11. REFERENCES

[1] Satyendra K. Vishwakarma, Prashant Upadhyaya, Babita Kumari, Arun Kumar Mishra "Smart Energy Efficient Home Automation System using IOT" In *2021 IEEE 11th Annual Computing and Communication Workshop and Conference (CCWC)* (pp. 1333-1338).
[2] Shardha Somani, Parikshit Solunke, Shaunak Oke, Parth Medhi, Prof. P. P. Laturkar "IOT Based Smart Security and Home Automation" *(WiSPNET)* (pp. 311-315). IEEE
[3] Tui-Yi Yang, Chu-Sing Yang, Tien-Wen Sung "A Dynamic Distributed Energy Management Algorithm of Home Sensor Network for Home Automation System" in 2016 Third International Conference on Computing Measurement Control and Sensor Network.
[4] M. Singh, A. Sharma, "Arduino-Based Classroom Automation", IJRASET, vol. 6, no. 2, 2019.
[5] Tushar Churasia and Prashant Kumar Jain "*Enhance Smart Home Automation System based on Internet of Things*" in Proceedings of the Third International Conference on I- SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC 2019) IEEE Xplore Part Number: CFP19OSVART; ISBN:978-1-7281-43657
[6] O. E. Ojo, M. K. Kareem, O. Samuel, and C. O. Ugwunna, "An Internet-of-Things based Real-time Monitoring System for Smart Classroom," Journal of the Nigerian Society of Physical Sciences, vol. 4, no. 2, pp. 297–309, May 2022.
7] A. R. Ani, S. Krishna, H. A., and U. A., "An Approach Towards Building an IoT Based Smart Classroom," in Proc. International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2018.
[8] R. Hassan and S. Salauddin, "Implementation of IoT based smart classroom: Room occupancy estimation, automatic seat allocation and environment monitoring," BSc. thesis, Dept. of Electronics and Communication Engineering, Brac University, Dhaka, Bangladesh, Apr. 2020.