A PROJECT REPORT ON

Bright Track Web – Enabled Motion Sensing Lighting System with ESP 32 and Dynamic Zone Control

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BY

Shivam Sharma
(2101321550054)

Pradosh Pandey
(2101321550044)

Nishant Sharma
(2101321550042)

Tanuj Sharma
(2101321550058)

UNDER THE GUIDANCE OF

Mr. RAJAT KISHOR VARSHNEY

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING (INTERNET OF THINGS),

GREATER NOIDA INSTITUTE OF TECHNOLOGY ENGG.INSTITUTE, GREATER NOIDA

Dr. A.P.J. Abdul Kalam Technical University, Lucknow

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Project Completion Certificate

Date: 15/05/2025

This is to certify that **Mr. Shivam Sharma** bearing Roll No.**2101321550054**, student of 4th year CSE-IoT has completed project program (KCS-851) with the Department of CSE-IoT from 10 February 2025 to 15 May 2025.

He worked on the Project Titled " **Bright Track web – Enabled motion sensing Lighting system with ESP 32 and Dynamic zone Control** " under the guidance of **Mr. Rajat Kishor Varshney.**

This project work has not been submitted anywhere for any degree.

Mr. Rajat Kishor Varshney
Assistant Professor, CSE-IoT

Dr. Indradeep Verma
HoD-IoT

Department of CSE-IOT

Session 2024-2025

Project Completion Certificate

Date: 15/05/2025

This is to certify that **Mr. Pradosh Pandey** bearing Roll No.**2101321550044**, student of 4th year CSE-IoT has completed project program (KCS-851) with the Department of CSE-IoT from 10 February 2025 to 15 May 2025.

He worked on the Project Titled " **Bright Track web – Enabled motion sensing Lighting system with ESP 32 and Dynamic zone Control** " under the guidance of **Mr. Rajat Kishor Varshney.**

This project work has not been submitted anywhere for any degree.

Mr. Rajat Kishor Varshney | **Dr. Indradeep Verma**

Assistant Professor, CSE-IoT | **HoD-IoT**

Department of CSE-IOT.

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Date: 15/05/2025

This is to certify that **Mr. Nishant Sharma** bearing Roll No.**2101321550042**, student of 4th year CSE-IoT has completed project program (KCS-851) with the Department of CSE-IoT from 10 February 2025 to 15 May 2025.

He worked on the Project Titled " **Bright Track web – Enabled motion sensing Lighting system with ESP 32 and Dynamic zone Control** " under the guidance of **Mr. Rajat Kishor Varshney.**

This project work has not been submitted anywhere for any degree.

Mr. Rajat Kishor Varshney
Assistant Professor, CSE-IoT

Dr. Indradeep Verma
HoD-IoT

Department of CSE-IOT.

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This is to certify that **Mr. Tanuj Sharma** bearing Roll No.**21013121550058**, student of 4th year CSE-IoT has completed project program (KCS-851) with the Department of CSE-IoT from 10-Feb 2025 to 15- May 2025.

He worked on the Project Titled " **Bright Track web – Enabled motion sensing Lighting system with ESP 32 and Dynamic zone Control** " under the guidance of **Mr. Rajat Kishor Varshney.**

This project work has not been submitted anywhere for any degree.

Mr. Rajat Kishor Varshney — **Dr. Indradeep Verma**

Assistant Professor, CSE-IoT — **HoD-IoT**

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ABSTRACT

Energy efficiency and automation have become crucial in modern smart building systems. Traditional lighting and fan control methods often lead to excessive power consumption, increasing electricity costs and environmental impact. "Bright Track" is an IoT-based web-enabled motion sensing lighting and fan system that optimizes energy usage using ESP32, motion sensors, and temperature sensors.

The system integrates PIR motion sensors to detect occupancy and automatically turn lights ON/OFF. Additionally, it uses temperature sensors DHT22 to monitor room temperature and turn fans ON when the temperature exceeds 24°C, ensuring a comfortable environment while preventing unnecessary energy usage. An air quality monitoring system MQ-135 detects CO_2 levels and humidity, improving indoor air quality. A cloud-based dashboard enables real-time monitoring and remote control, allowing users to track energy consumption and manually adjust settings as needed. The system also features dynamic zone control, where different areas operate independently based on occupancy and environmental conditions.

By integrating IoT, cloud computing, and automation, Bright Track offers a sustainable, cost-effective, and smart energy management solution for homes, offices, classrooms, and public spaces. The system reduces electricity consumption, enhances convenience, and contributes to a greener environment by ensuring that lights and fans operate only when necessary. Future enhancements include AI-based predictive analytics, integration with voice assistants (Google Assistant/Alexa), and solar power support to further optimize energy efficiency.

Bright Track is a step towards intelligent, eco-friendly automation, providing a smart, responsive, and energy-saving environment for modern spaces.

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Introduction

1.1 Introduction

In today's world, energy efficiency has become a priority due to the growing concerns over climate change and the rising costs of electricity. Buildings alone account for about 30% of global energy consumption, with lighting and heating, ventilation, and air conditioning (HVAC) systems being significant contributors (International Energy Agency [IEA], 2021). Traditionally, these systems often lead to wasteful energy consumption, especially when devices are left on unnecessarily. This problem is exacerbated in non-smart environments where manual control of lighting, fans, and other electrical appliances is common.[1]

"Bright Track" is an IoT-based motion-sensing lighting and fan system designed to address this issue by automating energy use in response to real-time conditions. The system leverages ESP32 microcontrollers, motion sensors PIR and temperature sensors DHT22 to automatically turn on/off lights and fans based on occupancy and room temperature. When a person enters the room, lights and fans activate, and when the room is empty, these devices turn off, saving energy. Additionally, fans are controlled automatically when the room temperature exceeds 24°C, ensuring comfort while maintaining energy efficiency. The system also incorporates air quality sensors to monitor CO_2 and humidity levels, which contribute to a healthier indoor environment.

With the help of a cloud-based dashboard, users can monitor and control the system remotely, making it a highly efficient and user-friendly solution for homes, offices, and public spaces. The automation not only reduces energy consumption but also promotes sustainability by ensuring that devices are only used when necessary.

1.2 Problem Statement

Energy wastage due to manual control of electrical appliances is a significant issue in residential, commercial, and public buildings. Many users forget to turn off lights and fans, leading to unnecessary power consumption and increased electricity costs. Additionally, fans are often left running even in unoccupied spaces or when cooling is not needed, further contributing to energy inefficiency.

Traditional systems lack automation and intelligence, requiring human intervention to manage lighting and ventilation. This results in inconsistent energy usage, higher carbon footprints, and reduced sustainability. Furthermore, poor air quality management in enclosed spaces affects health and comfort, particularly in offices, classrooms, and auditoriums.

To address these challenges, an IoT-based smart system is needed to automate lighting and fan control based on motion detection and temperature monitoring. This will reduce energy waste, lower electricity costs, and improve indoor air quality while providing a user-friendly remote monitoring solution via a cloud-based dashboard.

1.3 Identification of Need

With the rapid advancement of technology and urbanization, the demand for smart, automated solutions is increasing. Traditional lighting and fan systems rely on manual switching, which leads to wastage of electricity when users forget to turn off devices. Studies show that lighting and fans account for nearly 40% of total electricity consumption in residential and commercial buildings (U.S. Department of Energy, 2022). This excessive usage not only increases energy bills but also contributes to higher carbon emissions.

Additionally, in large spaces such as classrooms, offices, and auditoriums, fans operate continuously, even when cooling is unnecessary. Without temperature-based control, fans run inefficiently, leading to unnecessary energy expenditure. Moreover, poorindoor air quality caused by high CO_2 levels and humidity negatively impacts health, comfort, and productivity.

A smart, IoT-enabled automation system is needed to detect motion, monitor temperature, and control devices automatically. By using ESP32, PIR sensors, temperature sensors, and cloud-based dashboards, an energy-efficient, automated solution can be developed. This will not only reduce energy wastage but also enhance user convenience and environmental sustainability.

1.4 Objective

The primary objective of this project, "Bright Track: Web-Enabled Motion Sensing Lighting & Fan System," is to optimize energy consumption using IoT-based automation. This system aims to eliminate manual dependency by integrating motion, temperature, and air quality sensors to control lights and fans automatically.

The specific objectives of this project include:

1. **Automate Lighting & Fan Control Based on Occupancy:**

Use PIR motion sensors to detect movement and turn lights ON/OFF automatically. Ensure fans operate only when a person is present, reducing unnecessary power usage.

2. **Implement Smart Fan Control Based on Temperature:**

Use DHT22 temperature sensors to monitor room temperature. Automatically turn fans ON when the temperature exceeds 24°C and turn them OFF when cooling is not needed.

3. **Monitor Air Quality for a Healthier Environment:** Integrate MQ-135 sensors to measure CO_2 levels and humidity. Provide real-time air quality monitoring on the cloud-based dashboard.

4. **Develop a Cloud-Based Dashboard for Remote Monitoring & Control:**

Display real-time sensor data (temperature, humidity, air quality, energy usage). Allow users to remotely control lights and fans via a web-based interface.

5. **Optimize Energy Consumption & Reduce Costs:**

- Track power usage trends using an energy monitoring module.
- Reduce electricity bills and carbon footprint through smart automation.
- By achieving these objectives, Bright Track aims to create an efficient, automated, and cost-effective solution for homes, offices, and public spaces.

1.5 Uniqueness of the innovation

"Bright Track" stands out from traditional smart lighting and fan systems by integrating motion sensing, temperature-based automation, air quality monitoring, and cloud-based control into a single, intelligent system. Unlike conventional automation systems that only use motion sensors for lighting, Bright Track dynamically controls fans based on real-time temperature changes, ensuring optimal comfort while reducing energy consumption.

A unique feature of this system is its dynamic zone control, allowing different areas to function independently based on occupancy and environmental conditions. Additionally, the integration of air quality sensors MQ-135 provides real-time monitoring of CO_2 levels and humidity, enhancing indoor air quality. The cloud-based dashboard allows users to remotely monitor and control devices from anywhere, adding convenience and efficiency.

By combining IoT, smart sensors, and cloud computing, Bright Track offers a cost- effective, eco-friendly, and highly intelligent energy management solution, making it a pioneering innovation in smart automation.

1.6 Applications of Bright Track Web Enabled

1.6.1 Potential areas of application in industry/market in brief

"Bright Track" has a wide range of applications across residential, commercial, and industrial sectors, where energy efficiency and automation are crucial.

1. Smart Homes & Apartments – Automates lighting and fan control to reduce electricity bills and enhance convenience.

2. Offices & Workspaces – Ensures optimal energy usage by controlling devices based on occupancy and temperature.

3. Educational Institutions – Smart classrooms and auditoriums can benefit from dynamic zone control, improving energy efficiency.

4. Hospitals & Healthcare Centres – Air quality monitoring helps maintain a healthy indoor environment.

5. Hotels & Hospitality Industry – Enhances guest experience with smart automation while reducing operational costs.

6. Retail Stores & shopping malls – Optimizes lighting and ventilation in high- traffic areas.

7. Industrial & Manufacturing Facilities – Helps in energy monitoring and automation, leading to cost savings.

This versatile application range makes Bright Track a highly scalable solution for modern energy management.

1.6.2 Market potential of idea/innovation

The demand for smart home automation and energy-efficient solutions is rapidly growing, driven by rising energy costs, climate change concerns, and technological advancements. The global smart lighting and fan control market is projected to grow at a CAGR of 20% from 2024 to 2030, reaching $30 billion by 2030. Bright Track has strong market potential in industries:

- Residential Sector – The smart home market is booming, with millions of homeowners adopting IoT-based automation.
- Commercial Buildings & Offices – Businesses seek energy-efficient solutions to lower operational costs.
- Educational Institutions – Schools and universities are increasingly adopting smart classrooms to improve sustainability.
- Hospitality & Retail Industry – Hotels and malls invest in smart energy-saving systems .

With IoT adoption increasing worldwide, Bright Track's unique combination of motion sensing, temperature-based automation, and air quality monitoring makes it a highly competitive and scalable product. Expanding its features with AI-based analytics and voice assistant integration can further enhance its market potential

Chapter 2

Literature Survey

2.1 Review of Literature

The development of smart lighting and fan control systems using IoT-based automation has been a growing area of research due to increasing energy consumption concerns. Several studies have explored motion-sensing, temperature-based automation, and cloud-based monitoring to improve energy efficiency and reduce electricity wastage. This section reviews relevant literature on IoT-based smart home automation, motion detection systems, temperature-based control, and energy management solutions.

Research by Gubbi et al. highlighted the importance of IoT in energy management, stating that integrating sensors with cloud computing allows for real-time energy tracking and optimization [2]. Similarly, Kumar & Mallick proposed an IoT-based smart home automation system, emphasizing remote monitoring and automatic control of electrical devices to enhance energy savings. Their findings showed that such systems could reduce electricity consumption by up to 30% [3].

Studies on motion detection-based automation have demonstrated significant energy savings. Jadhav & Patil developed a PIR sensor-based automatic lighting system, which reduced unnecessary energy use by automatically turning lights ON/OFF based on occupancy. However, their study noted that PIR sensors have limitations in detecting slow movements [4]. To address this, Li et al. introduced mm Wave radar sensors, which offer better motion detection accuracy in smart lighting systems [5].

Temperature-based automation has also been widely studied. Shinde & Kulkarni developed an automatic fan control system using DHT22 sensors and microcontrollers. Their study concluded that temperature-controlled fan operation could reduce energy consumption by up to 40% in warm climates [6]. Mishra et al. further enhanced this approach by integrating machine learning algorithms to predict fan usage patterns based on historical temperature data [7].

Air quality monitoring has gained importance in modern IoT systems. Gupta et al.developed an MQ-135 sensor-based air quality monitoring system that measures CO_2 levels and alerts users when air quality deteriorates. They concluded that such systems improve indoor health conditions, especially in offices and classrooms [8].

The role of cloud computing in IoT-based automation has been extensively studied. Ahmed & Hassan proposed a real-time cloud dashboard for monitoring energy consumption, allowing users to remotely control devices via mobile or web applications. Their research emphasized that cloud-based control enhances user convenience and optimizes energy use [9].

While significant research has been conducted on IoT-based automation for energy efficiency, several gaps remain unaddressed in existing smart lighting and fan control systems. Most studies focus on either motion-based lighting control or temperature- based fan automation, but few integrate both lighting and ventilation control into a single system. This lack of integration leads to incomplete automation, requiring multiple independent systems to manage energy consumption effectively.

Another gap lies in dynamic zone control, where different areas within a building can be controlled separately based on occupancy and environmental conditions. Most existing solutions apply a single control mechanism for an entire room, leading to inefficient energy use in larger spaces such as offices, classrooms, and auditoriums.

Additionally, while air quality monitoring has been explored in research, few studies integrate air quality data into an adaptive energy control system. Poor indoor air quality impacts comfort, health, and productivity, yet many existing smart systems do not include real-time CO_2 and humidity monitoring.

Furthermore, most IoT-based systems lack cloud-based energy consumption tracking, making it difficult for users to analyze and optimize their electricity usage patterns.

The "Bright Track" system addresses these research gaps by combining motion-sensing lighting, temperature-based fan control.

Chapter 3

Problem Formulation and Proposed Work

3.1 Problem Statement

Energy wastage due to manual operation of lights and fans is a significant challenge in homes, offices, schools, and public buildings. People often forget to turn off appliances, leading to higher electricity costs and increased carbon footprints. Additionally, fans run continuously, even when cooling is unnecessary, resulting in inefficient energy use.

Traditional lighting and fan systems lack intelligent automation and require human intervention. There is also no integration with environmental sensors, meaning temperature and air quality fluctuations go unmanaged, affecting comfort and indoor air quality.

To solve this issue, an IoT-based smart automation system is needed to automatically control lights and fans based on motion detection and temperature monitoring. This system should also include air quality monitoring and cloud-based control, allowing users to optimize energy consumption, improve comfort, and remotely manage devices. The goal is to create a cost-effective, energy-efficient, and smart environmental management solution.

3.2 Proposed System

The "Bright Track" system is an IoT-based, web-enabled smart automation solution that intelligently controls lights and fans based on motion detection and room temperature. It uses ESP32 microcontrollers, PIR motion sensors, and temperature sensors DHT22 to automate energy-efficient operations.

Key Features of the Proposed System:

1. **Motion-Based Lighting Control –** Lights turn ON when motion is detected and turn OFF

when the room is vacant, reducing electricity wastage. Temperature-Based Fan Control the fan automatically turns ON when room temperature exceeds 24°C and turns OFF when cooling is not needed, optimizing energy use.

2. **Air Quality Monitoring –** CO_2 and humidity levels are monitored using MQ-135 sensors, ensuring better indoor air quality.

3. **Cloud-Based Dashboard –** Users can remotely monitor and control lights and fans from a web interface.

4. **Energy Consumption Tracking –** The system records real-time energy usage, allowing users to analyze and optimize power consumption.

This proposed system eliminates manual dependency, enhances energy efficiency, improves comfort, and provides a smart, automated solution for homes, offices, classrooms, and public spaces.

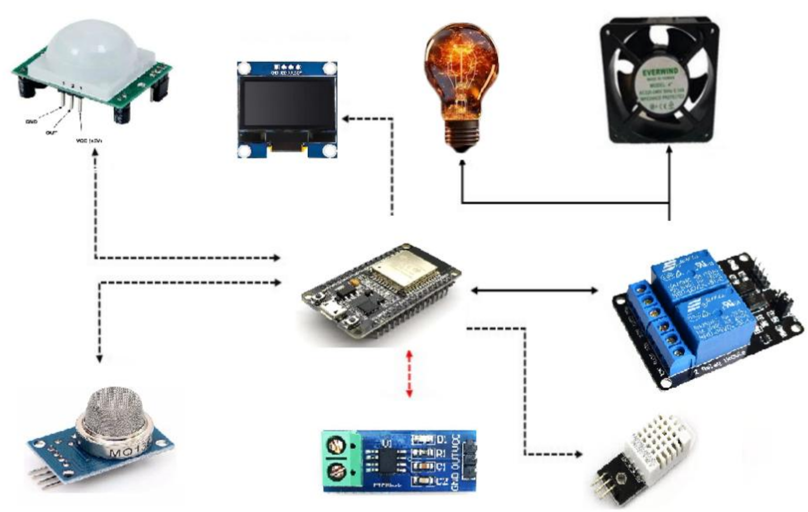

Fig.1: Block diagram of Bright Track web

3.3 Advantage of proposed system

The **"Bright Track"** IoT-based automation system offers multiple advantages in terms of energy efficiency, cost savings, and user convenience.

1. **Energy Efficiency & Cost Savings**

Reduces unnecessary power consumption by automatically turning lights and fans ON/OFF based on motion and temperature.

Optimizes fan usage by ensuring it only runs when the temperature exceeds 24°C, preventing excessive energy use.

Energy consumption tracking helps users analyze and reduce their electricity bills.

2. **Smart & Automated Control**

Motion sensors ensure lights operate only when someone is present.

3. **Cloud-based dashboard** allows remote monitoring and manual control via a web interface.Improved Indoor Air Quality

Air quality sensors monitor CO_2 levels and humidity, helping to create a healthier environment.

4. **Convenience & User-Friendly Operation**

No manual intervention required – the system works autonomously. Users can remotely control devices anytime, anywhere.

5. **Scalability & Versatility**

Can be implemented in homes, offices, schools, hotels, and commercial spaces. Easily expandable with AI, voice assistants, and additional sensors.

This smart, cost-effective, and eco-friendly solution improves efficiency, reduces electricity waste, and enhances user comfort

3.4 Limitations

While "Bright Track" offers numerous advantages, there are some limitations:

1. **Initial Setup Cost:**

Sensors, ESP32, and cloud services may require an initial investment, making it less affordable for some users.

2. **Internet Dependency:**

The cloud-based dashboard requires an active internet connection for remote monitoring and control. If the internet goes down, users may lose access to remote features.

3. **Sensor Accuracy & Limitations:**

Motion sensors (PIR) might not detect very slow movements, potentially causing false OFF states. Temperature sensors may have slight variations in readings, affecting fan control .

4. **Limited Control in Shared Spaces:**

In multi-user environments (offices, auditoriums, etc.), motion-based control might not work effectively if multiple users have different preferences.

Despite these limitations, **Bright Track remains a highly efficient and scalable solution** for smart energy management.

Chapter 4

Feasibility Study

4.1. Technical Feasibility

4.1.1 Arduino IDE:

A detachable, dual-inline-package (DIP) ATmega328 AVR microprocessor serves as the foundation for the Arduino UNO R3 microcontroller board. Twenty digital input/output pins are included on it, six of which can be utilized as PWM outputs and the other six for computer programs. Because of its large support base, the Arduino is a fairly simple platform to begin working with embedded electronics.

The Arduino IDE becomes an invaluable tool for documenting code and project details. Its user-friendly interface makes coding easier for both novice and seasoned developers. Developers can include comments and annotations directly in the code, explaining the functionality of particular sections or giving context for particular decisions.

The Arduino IDE, users are presented with an interface that is easy to navigate and caters to a wide range of developers, from beginners to seasoned pros. This interface is quite helpful during the development process since it makes it possible to add comments and annotations straight into the source. These annotations clarify the purpose of particular code segments and offer crucial background information for making decisions throughout the development process.

The Arduino IDE makes it possible to create thorough project documentation with precision. This documentation includes an overview of the project, a description of its goals, and a list of the components that were used, and clear wiring diagrams. Developers may guarantee that this

Documentation becomes an integral part of the project, supporting teamwork, aiding in debugging, and creating the foundation for future project expansion, by incorporating it within the IDE.

The Arduino IDE presents itself as an indispensable tool for developers to document, annotate, and produce thorough reports, going beyond its function as a simple coding environment. By virtue of these characteristics, the Arduino IDE improves the overall effectiveness of the report-making process by streamlining the communication and presenting components of Arduino-based projects.

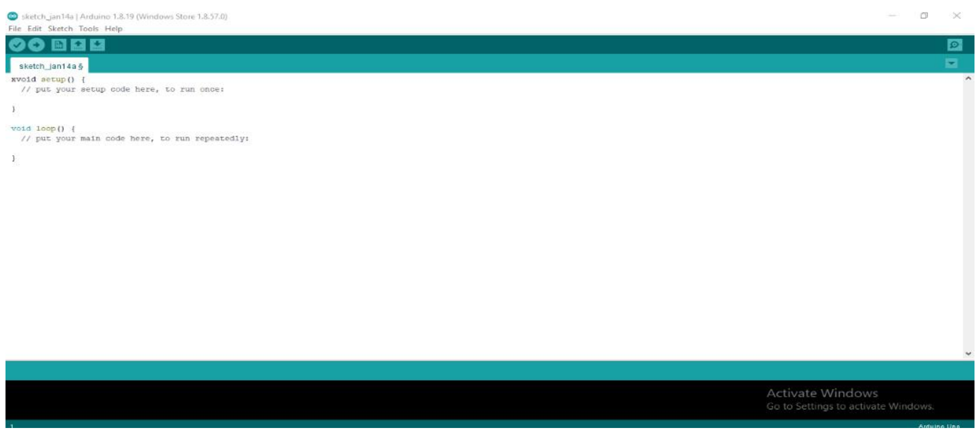

Fig.2: Arduino IDE

4.1.2 ESP 32:

The ESP32, developed by Espressif Systems, is a renowned microcontroller platform celebrated for its powerful features and cost-effectiveness. It features a dual-core Tensilica Xtensa LX6 microprocessor, capable of operating at up to 240 MHz, which supports efficient multitasking and complex computations. One of its standout features is the integrated Wi-Fi and Bluetooth capabilities, supporting 802.11 b/g/n Wi-Fi and Bluetooth 4.2, including Classic Bluetooth and Bluetooth Low Energy (BLE), making it ideal for IoT (Internet of Things) applications.

Equipped with a rich set of peripherals, the ESP32 includes multiple UARTs, SPI, I2C, I2S, and PWM interfaces, enabling it to interface with various sensors, actuators, and other hardware components. Additionally, it offers 18 channels of 12-bit ADC (Analog to Digital Converter) and 2 channels of 8-bit DAC (Digital to Analog Converter) for precise analog measurements and signal generation. The ESP32 is designed with energy efficiency in mind, featuring various power modes such as deep sleep, light sleep, and dynamic frequency scaling, crucial for battery- powered devices.

Development for the ESP32 is supported by the ESP-IDF (Espressif IoT Development Framework), a comprehensive software development kit, and it is also compatible with the Arduino IDE, making it accessible to hobbyists and beginners alike. This versatility allows the ESP32 to be used in a wide range of applications, including IoT devices, home automation systems, health monitoring devices, industrial control systems, and robotics. Its connectivity options are particularly beneficial for smart home devices, wearable electronics, and industrial

The ESP32's development environment is further enhanced by an extensive ecosystem of tools and resources. The ESP-IDF provides comprehensive software libraries and example code facilitating rapid development and deployment of applications. For beginners and hobbyists, the Arduino IDE offers a simplified interface and a vast repository of libraries tailored to the ESP32, making it easier to start with basic projects and gradually advance to more complex

In practical applications, the ESP32's low power consumption features are especially advantageous. For IoT devices, the ability to switch to deep sleep mode can significantly extend battery life, making it suitable for remote monitoring systems where battery replacement is impractical. In home automation, the combination of Wi-Fi and Bluetooth connectivity allows the ESP32 to seamlessly integrate with various smart devices, creating a cohesive and intelligent home environment. Health monitoring devices benefit from the ESP32's BLE capabilities, enabling real-time data transmission with minimal power usage, essential for wearable technology.

The ESP32's robust performance and diverse features also make it an excellent choice for industrial control systems. Its multiple I/O interfaces and high processing power enable it to handle complex tasks such as real-time data processing and machine control. In robotics, the ESP32 can manage sensors, motors, and communication systems, providing a versatile platform for building sophisticated robotic systems.

Moreover, the active and growing ESP32 community significantly contributes to its success. Developers continuously contribute to an extensive collection of open-source libraries, tutorials, and forums. This collaborative environment aids in troubleshooting and problem-solving while fostering innovation through the sharing of new projects and ideas.

The ESP32 also supports various operating systems and real-time operating systems (RTOS), such as FreeRTOS, allowing for real-time task management and precise control over hardware resources. This suitability for applications requiring deterministic performance makes it ideal for audio processing, real-time data acquisition, and control systems.For security-conscious applications, the ESP32 offers robust security features, including hardware encryption, secure boot, and flash encryption, ensuring data protection both at rest and during transmission. These features are particularly important in IoT applications, where security is a major concern due to the increasing number of connected devices.

Additionally, the ESP32 can easily integrate with cloud platforms like AWS, Google Cloud, and Azure. This capability enables developers to build scalable IoT solutions that leverage cloud computing resources for data analytics, machine learning, and remote management.

In educational settings, the ESP32 is frequently used to teach students about embedded systems, programming, and IoT concepts. Its affordability and ease of use make it an excellent tool for hands-on learning and experimentation. Many educational institutions and makerspaces use the ESP32 to introduce students to real-world applications of technology, fostering a new generation of engineers and developers.

Overall, the ESP32's combination of advanced features, extensive connectivity options, energy efficiency, and strong community support makes it a highly versatile and widely used microcontroller. Whether in IoT, industrial automation, health monitoring, robotics, or education, the ESP32 provides a robust platform for innovation and development.

Fig.3: ESP 32

4.1.3 PIR SENSOR:

sensor that measures infrared light radiating from objects. PIR sensors mostly used in PIR-based motion detectors. Also, it used in security alarms and automatic lighting applications. The below image shows a typical pin configuration of the PIR sensor, which is quite simple to understand the pinouts.

The PIR sensor consist of 3 pins:

• **Pin1** corresponds to the drain terminal of the device, which connected to the positive supply 5V DC. 12

• **Pin2** corresponds to the source terminal of the device, which connects to the ground terminal via a 100K or 47K resistor. The Pin2 is the output pin of the sensor. The pin 2 of the sensor carries the detected IR signal to an amplifier from the

• **Pin3** of the sensor connected to the ground. Generally, PIR sensor can detect animal/human movement in a requirement range. PIR is made of a pyroelectric sensor, which is able to detect different levels of infrared radiation. The detector itself does not emit any energy but passively receives it. It detects infrared radiation from the environment.

The pyroelectric device will create a sudden electric signal when the optics makes the pyroelectric material respond to the infrared radiation coming from the human body with temperature. Just as a human or animal comes by, the PIR sensor intercepts the first signal it detects. This causes

There is negative distance between the two buses in the graph. As soon as the human body is away from the sensing sensor, the machine detects a negative difference between the two bisects. This type of sensor does not emit energy that can be detected by space agencies. Infrared radiation from our bodies reaches the device which causes an alarm to sound. Any object carrying heat is always sending out infrared rays around it. Between 36° C and 27 ° C is the typical range for the surface temperature of a human body. Its main radiant energy is found within the 8 um-12 um wavelength range. They are designed to include infrared detector (infrared probe) and also alarm control sections. A pyroelectric detector is the type of infrared detector that is found in the most applications. It detects human radiation and changes it into an electrical current. Shining the infrared radiation directly from the detector on humans will result in an increase in detector temperature that causes output. That said, the range you can detect things will not go beyond what it currently is. In order to increase how far the detector can detect something, an optical system must pick up the infrared rays. Normally, the system for focusing infrared light is made of plastic optical reflection or plastic Fresnel lenses. When someone moves in the detector, the lens picks up their body's infrared energy even through the clothing before it focuses the energy on the sensor. As the human body moves in surveillance mode, it steps into a particular field of view bit by bit and leaves it after a few steps. The pyroelectric sensor sees the moving human body for a while and then does not see it, so the infrared radiation of human body constantly changes the temperature of the pyroelectric material. So that it outputs a corresponding signal, which is the alarm signal.

The PIR sensor, priced between 350 and 420 rupees, offers precise measurement capabilities for detecting and quantifying forces applied to it and some specifications:

- Indoor passive infrared: Detection distances range from 25 cm to 20 m.
- Indoor curtain type: The detection distance ranges from 25 cm to 20 m.
- Outdoor passive infrared: The detection distance ranges from 10 meters to 150 meters.
- Outdoor passive infrared curtain detector: distance from 10 meters to 150 meters.
- Common PIR sensors have an 180-degree range.

Sources: You can purchase force sensors from various sources, including online retailers such as Amazon, electronics suppliers like Digi-Key or Mouser, and specialized sensor manufacturers such as TE Connectivity or Honeywell. Additionally, local electronics stores or industrial equipment suppliers may also carry force sensors. When buying a force sensor, consider factors such as price specifications, brand reputation, and customer reviews to ensure you get a reliable and suitable product for your application.

Fig.4: PIR Sensor

4.1.4 DHT22

The DHT22, also known as AM2302, is a widely used digital temperature and humidity sensor in IoT, home automation, and environmental monitoring systems. It provides reliable measurements with moderate accuracy, making it suitable for various applications where cost-effectiveness and simplicity are key factors.

The DHT22 is a low-cost digital sensor that combines temperature and humidity sensing in a single module. Key features include a temperature range from -40°C to +80°C with an accuracy of ±0.5°C, a humidity range from 0% to 100% with ±2% accuracy, digital output using a single-wire communication protocol, a sampling rate of 0.5 Hz (one reading every 2 seconds), and operation at 3.3V to 5V DC power supply. Compared to its predecessor, the DHT11, the DHT22 offers higher accuracy and a wider measurement range, making it more suitable for precision applications.

The DHT22 uses a thermistor for temperature sensing and a capacitive humidity sensor for moisture detection. For temperature sensing, the sensor contains a Negative Temperature Coefficient (NTC) thermistor, which decreases resistance as temperature increases. The microcontroller reads this resistance change and converts it into a digital temperature value. For humidity sensing, the sensor uses a moisture-sensitive capacitor that changes capacitance based on air humidity, converting this change into a digital signal.

Data transmission occurs via a single-wire serial interface. The microcontroller sends a start signal to request data, the DHT22 responds with a 40-bit digital packet containing 16 bits for humidity, 16 bits for temperature, and 8 bits for checksum. Checksum validation ensures data integrity.

The DHT22 can be easily connected to popular development boards like Arduino, ESP8266, ESP32, and Raspberry Pi. For hardware connections, the VCC pin connects to 3.3V or 5V, the GND pin to ground, and the data pin to a digital GPIO pin with a pull-up resistor.

Due to its affordability, ease of use, and moderate accuracy, the DHT22 is used in various fields. In smart home automation, it is used in thermostats and HVAC systems to adjust heating and cooling based on real-time temperature and in humidity monitoring to prevent mold growth. Weather stations use it to measure outdoor and indoor temperature and humidity for weather logging. In agriculture and greenhouse monitoring, it ensures optimal growing conditions by tracking soil and air humidity. Industrial and warehouse monitoring systems use it to prevent equipment damage by detecting extreme temperature and humidity changes. It is also used in IoT and wearable devices for environmental sensing.

The DHT22 has several advantages, including low cost compared to industrial-grade sensors, combined temperature and humidity sensing in one module, digital output eliminating the need for analog-to-digital conversion, and a wide operating range from -40°C to +80°C. However, it has limitations such as a slow response time with a 2-second delay between readings, unsuitability for high-precision applications like medical devices, and potential signal loss with long cable lengths.The DHT22 is a versatile and cost-effective sensor for temperature and humidity monitoring in IoT, smart homes, and industrial applications. While it lacks the extreme precision of high-end sensors like BME280 or SHT31, its simplicity and affordability make it a popular choice for hobbyists and developers. For projects requiring faster response times or higher accuracy, alternatives like DS18B20 for temperature-only or BME280 for pressure, temperature, and humidity may be more suitable. However, for most general-purpose applications, the DHT22 remains a reliable and efficient choice.

Fig.5: DHT-22 Sensor

4.1.5 MQ-135

The MQ-135 is a semiconductor gas sensor widely used for detecting various harmful gases in the environment, particularly in air quality monitoring systems. This section provides a detailed examination of its working mechanism, technical specifications, and practical applications.

The MQ-135 is a metal oxide semiconductor (MOS) type sensor capable of detecting multiple gases including: Ammonia (NH_3), Alcohol ,Smoke ,Carbon dioxide (CO_2)

Other harmful volatile organic compounds (VOCs)

Key specifications include:

Operating voltage: 5V DC

Detection range: 10-1000 ppm (parts per million)

Heater consumption: ~800mW

Analog and digital output option**s**

Preheating time: 24-48 hours for stable readings

The sensor operates on the principle of conductivity changes in its tin dioxide (SnO_2) sensing layer when exposed to target gases:

Heating Element: The sensor contains a heating coil that maintains an optimal operating temperature (typically 200-300°C) to facilitate chemical reactions.

Gas Interaction: When target gases come into contact with the heated sensing surface, they undergo oxidation/reduction reactions.

Resistance Change: These reactions alter the sensor's electrical resistance proportionally to gas concentration.

Signal Output: The resistance change is converted to either Analog voltage (0-5V) proportional to gas concentration. Digital signal (high/low) when using comparator circuits

Sensitivity: Varies for different gases (typically highest for NH_3 and NOx)

Response Time: 10-30 seconds to reach 90% of final reading

Recovery Time: 30-60 seconds to return to baseline

Temperature/Humidity Dependence: Requires compensation algorithms for accurate measurements

Lifespan: Approximately 5 years with continuous operation

Typical Applications:

- Indoor Air Quality Monitoring
- Detects CO_2 buildup in offices/schools
- Identifies VOC emissions from furniture/paints
- Industrial Safety Systems
- Ammonia leak detection in refrigeration plants
- NOx monitoring in manufacturing facilities
- Preheating: Requires 24-48 hours of continuous power for stabilization
- Baseline Establishment: Should record normal air readings as reference

Environmental Compensation:

When compared to other air quality sensors, the MQ-135 presents several distinct advantages and limitations. Its primary benefits include significantly lower cost than electrochemical sensors, a wider detection range than many specialized gas sensors, and robust construction that makes it suitable for harsh environments. However, the sensor has notable drawbacks, including its non-selective nature (responding similarly to multiple gases rather than targeting specific ones) and its requirement for temperature and humidity compensation to maintain accuracy. Additionally, its response time is slower compared to some more advanced sensor technologies. Recent developments in gas sensing technology are addressing some of these limitations through innovations such as integrated temperature/humidity compensation circuits, AI-powered pattern recognition algorithms for improved gas identification, and the development of low-power versions specifically designed for IoT applications. The ongoing trend toward miniaturization is also making these sensors increasingly viable for wearable devices and other compact applications. These advancements are gradually bridging the gap between the MQ-135's cost-effectiveness and the performance characteristics of more expensive, specialized gas sensors.

- **Mounting**: Position away from direct airflow to prevent rapid aging
- **Ventilation**: Ensure adequate air circulation around sensor
- **Power Management**: Use pulsed heating to reduce power consumption
- **Data Interpretation**: Combine with other sensors for better accuracy

The MQ-135 remains a popular choice for cost-sensitive air quality monitoring applications, offering reasonable performance despite its limitations. Proper implementation and calibration are essential for obtaining reliable measurements in real-world conditions. For applications requiring higher specificity, combining the MQ-135 with other specialized sensors often yields optimal results.

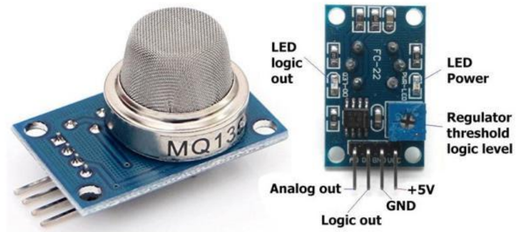

Fig.6: MQ-135 Sensor

4.1.6 Resistor:

A resistor is a fundamental electronic component that opposes the flow of electric current. Its primary function is to limit or control the amount of current flowing through a circuit. Resistors are ubiquitous in electronic devices, serving a crucial role in regulating voltage, dividing circuits, and protecting components.

The fundamental property that defines a resistor is its resistance, measured in ohms (Ω). Resistance is the opposition to the flow of electric current, and it depends on the material, length, and cross-sectional area of the resistor. The relationship between voltage (V), current (I), and resistance (R) is described by Ohm's Law: V = I * R.

Resistors come in various types and shapes, catering to different applications. One common type is the fixed resistor, which has a predetermined resistance value that remains constant. Variable resistors, on the other hand, allow the adjustment of resistance manually or automatically.

Potentiometers and rheostats are examples of variable resistors frequently used for tuning circuits or controlling volume in electronic devices.

The physical construction of resistors varies based on their intended use. Carbon composition resistors consist of a mixture of carbon and insulating material. Metal film resistors utilize a thin metal film on a ceramic base, providing greater precision and stability. Wire wound resistors employ a coiled wire, often made of a resistive alloy, for applications requiring high power handling capabilities.

Resistors play a crucial role in voltage division circuits, where they create a specific voltage droacross a portion of the circuit. This principle is frequently applied in voltage dividers, control over voltage levels within electronic systems. Moreover, resistors are integral in protecting sensitive electronic components by limiting the current that flows through them.

In addition to their primary function in limiting current, resistors find application in signal processing circuits. They influence the amplitude and frequency response of signals, contributing to the shaping and filtering of electrical signals. In audio applications, for instance, resistors are commonly used in conjunction with capacitors to design filters that pass or attenuate specific frequency ranges.

Resistors are also vital in the realm of integrated circuits (ICs) and microelectronics. They are employed in pull-up and pull-down resistor networks to establish known states in digital circuits. Pull-up resistors, for example, ensure that an input signal to a microcontroller is in a defined state when no other active device is driving it.

Furthermore, resistors are crucial for safety and power dissipation in electronic systems. High-power resistors can absorb and dissipate significant amounts of heat generated during normal operation. This prevents electronic components from overheating and ensures the reliability of the entire system.

In conclusion, resistors are fundamental components in electronic circuits, providing essential functions such as current limitation, voltage division, and signal processing. Their versatility and widespread use make them indispensable in various applications, from basic electronic devices to complex integrated circuits, contributing significantly to the functionality and reliability of modern electronic systems.Resistors play a pivotal role in the intricate world of electronics, acting as indispensable components that influence the behavior of electric circuits. Their ability to regulate current flow and manage voltage levels makes them essential for achieving precision, control, and safety in electronic systems.

One significant aspect of resistors is their impact on power dissipation. When electric current passes through a resistor, it encounters opposition, leading to the conversion of electrical energy into heat. This characteristic is particularly crucial in high-power applications where resistors are strategically employed to absorb and dissipate excess energy, preventing overheating and potential damage to sensitive electronic components.

In electronic circuits, resistors are often used in conjunction with other components, such as capacitors and inductors, to form filters that modify the frequency response of signals. This collaborative effort enables engineers to tailor the performance of a circuit to specific requirements, allowing for the selective transmission or attenuation of certain frequencies. The careful integration of resistors in signal processing applications contributes to the creation of audio equalizers, tone controls, and various filtering systems that shape the output signal according to desired characteristics.

The concept of resistance also extends its influence to the field of sensors. In devices like thermistors and photo resistors, the electrical resistance changes in response to variations in temperature or light intensity. This property makes resistors crucial elements in the development of sensors for temperature monitoring, ambient light sensing, and other applications where a measurable electrical response correlates with environmental changes.Resistors are not confined to passive roles; they actively contribute to the stability and reliability of electronic systems. Pull-up and pull-down resistors are commonly employed in digital circuits to ensure well-defined voltage levels when inputs are not actively driven. This is particularly important in microcontroller-based systems, where maintaining clear and consistent logic states is vital for proper operation.

Variable resistors, including potentiometers and rheostats, offer a dynamic element to circuit design. These components allow users to manually adjust resistance, offering a practical means of tuning circuits, controlling volume in audio devices, or setting specific parameters in various applications. The versatility of variable resistors provides a hands-on approach to circuit optimization, allowing for real-time adjustments to meet changing requirements.

In the context of electronic manufacturing, precision and reliability are paramount. Modern manufacturing processes have led to the development of resistors with high precision and stability, ensuring consistent performance across different units. This is particularly critical in applications such as medical devices, aerospace systems, and communication equipment, where the reliability and accuracy of electronic components are non-negotiable.

In conclusion, the intricate and multifaceted nature of resistors extends beyond their fundamental role in limiting current and controlling voltage. Their impact spans diverse applications, from power dissipation and signal processing to sensor technology and circuit tuning. As electronic systems continue to evolve, resistors remain at the forefront, contributing to the efficiency, stability, and adaptability of modern electronics.The resistor is available at prices ranging from a minimum of 2 rupees to a maximum of 3 rupees and some specifications:

- **Resistance** value: Expressed in ohms (Ω)
- **Tolerance**: Percentage indicating the maximum deviation from the specified resistance
- **Power rating:** Maximum power the resistor can dissipate without damage
- **Temperature coefficient:** Change in resistance per degree Celsius change in temperature (if applicable)

- **Dimensions:** Length, width, and height of the resistor package
- **Lead spacing:** Distance between the resistor leads for through-hole resistors
- **Additional characteristics**: Stability, noise level, voltage coefficient, etc.

Sources: The resistor can be sourced from various electronics suppliers or online marketplaces such as Amazon, Digi-Key, or Mouser Electronics. Additionally, local electronics stores or specialized component shops may also carry resistors.

Fig.7: Resistor

4.1.7 OLED Module :

OLED (Organic Light-Emitting Diode) modules have rapidly overtaken LCDs in many embedded and consumer-device applications thanks to their self-emissive pixels, true blacks, wide viewing angles, and fast response times. Available in monochrome, graphic, full-color, and even flexible or transparent formats, OLED displays eliminate the need for backlighting, reducing both component count and power draw—particularly when rendering dark UIs. They support standard interfaces (SPI, I^2C, or parallel) and can be driven via passive-matrix (PMOLED) or active-matrix (AMOLED) schemes, making them compatible with microcontrollers like Arduino and ESP32. Typical supply voltages hover around 3.3 V for logic and 5 V for power, and power consumption scales with the number of lit pixels (often 0.05–0.5 W total). Modules range from tiny 0.49″ monochrome 128×32 displays to vibrant 320×240 RGB panels, finding roles in wearables, industrial controls, automotive dashboards, and IoT dashboards. An active open-source ecosystem—centered on libraries such as Adafruit_SSD1306 and U8g2 and frameworks like ESP-IDF—further accelerates development, while MCU-level security features (secure boot, flash encryption) safeguard data on screen.

Electrical Connection

Power Pins: VCC (3.3 V/5 V), GND

Control Pins: CS (chip select), DC (data/command), RST (reset)

Data Pins: SCL/SCK (clock), SDA/MOSI (data), optional MISO for read back Orient Display.

Initialization Sequence Toggle RST low → high to reset the display. Send commands to configure memory addressing mode, multiplex ratio, display offset, and contrast. Issue the "Display ON" command to start rendering.

Data Transmission

Command Bytes: DC = 0; set column/page addresses and display parameters.

Data Bytes: DC = 1; transfer pixel bitmap or character data.

High-level libraries (e.g., Adafruit_SSD1306, U8g2) abstract these steps into simple drawPixel(), print(), and display() method.

Fig.8: OLED Module

4.1.8 LED BULB :

Light-Emitting Diodes (LEDs) have transformed the way we illuminate our world, offering unmatched energy efficiency, longevity, and directional control. Building on these strengths, “zero-watt” LED bulbs push the boundaries even further, consuming virtually no power—often well below one watt—while providing sufficient illumination for night-lights, indicator lamps, and decorative accents.

At the heart of a zero-watt LED bulb is the familiar principle of electroluminescence: when electrons and holes recombine in a semiconductor junction, they emit photons. By selecting high-efficiency LED die—typically gallium nitride (GaN) for white or cool-white light—and driving them at low current (often 5–10 mA), one can achieve visible output while keeping power draw to a bare minimum. Instead of relying on bulky transformers or high-wattage drivers, zero-watt bulbs employ a minimalist front end: a small capacitive or resistive dropper directly from the AC mains.A typical zero-watt LED circuit begins with the 230 V AC supply passing through an X-rated safety capacitor (0.22 μF to 0.47 μF) or a high-value resistor to limit inrush current. This “lossy” component drops most of the voltage without dissipating large amounts of heat. The resulting lower AC voltage is then rectified—either through a compact bridge of 1N4007 diodes or a pair of series diodes—to produce pulsed DC. A zener diode provides rough regulation, clamping the voltage to a level safe for the LED string. Finally, one or more LEDs, wired in series or a simple series-parallel array, convert this regulated current into light. A small electrolytic or film capacitor (if used) smooths out flicker, yielding a steady glow.

Despite the simplicity, these bulbs deliver surprising performance:

Ultra-Low Power Consumption: Typically 0.3 W to 1 W total, with each LED die drawing only a few milliamps—translating to near-zero cost on your electricity bill.

Long Lifespan: With minimal thermal stress and robust semiconductor materials, zero-watt LED bulbs often outlast conventional LEDs, boasting lifetimes of 50,000 hours or more.

Directional Illumination: By nature, LEDs emit light in a focused beam, eliminating the need for reflectors and allowing precise aiming—ideal for path markers, cabinet lights, or accent fixtures.

Compact, Retrofit-Friendly Form Factor: Many designs can be housed within the shell of an old bayonet or E27 bulb, converting standard sockets into ultra-efficient night-lights with no external driver.

Key Specifications for a DIY Zero-Watt LED Bulb

Input: 220–240 V AC via a capacitive dropper (0.22 µF, X2-rated) or a series resistor (1MΩ,½ W)

Rectifier: Four 1N4007 diodes in bridge configuration (or two in series for half-wave)

Regulator: 3.3 V to 5.1 V zener diode (0.5 W rating)

LED Array: 1–3 high-efficiency white LEDs (GaN) in series, each with a forward voltage of 2.8–3.2 V

Smoothing Capacitor (optional): 10 µF, 50 V electrolytic

Power Draw: ≈0.5 W (at mains voltage of 230 V)

Luminous Output: 20–60 lumens (sufficient for subdued night-lighting)

Safety and Practical Considerations

Working directly with mains voltage carries inherent risk. All components must be X- or Y-rated for mains use, insulated within a non-conductive housing, and assembled by someone familiar with electrical safety and soldering. Never touch live parts, and always disconnect power before adjustments.

Applications and Advantages

Zero-watt LED bulbs excel in scenarios where low-level lighting is needed continuously or for long durations:

Night-Lights: Gentle illumination in hallways, bathrooms, or children's rooms.

Indicator Lamps: Panel indicators, status lights on appliances, or power-on signals.

Decorative Accents: Under-cabinet lighting, cove lights, and ornamental fixtures where glare must be minimized.

Energy-Harvesting Systems: Paired with micro-solar panels or small batteries, these bulbs can run indefinitely off trickle power sources.

Fig 9 : Bulb

4.1.9 Fan :

Electric fans are ubiquitous devices that convert electrical energy into airflow, providing effective cooling and ventilation in homes, offices, and industrial facilities. Leveraging the principles of electromechanical conversion, fans have evolved from simple blade assemblies to sophisticated systems featuring aerodynamic design, brushless motors, and smart controls.

At the core of every fan is an electric motor—most commonly an induction (AC) or brushless DC (BLDC) motor—that spins a set of blades. As the blades rotate, they impart momentum to the surrounding air, creating a flow that can be directed and diffused for maximum comfort. Unlike passive ventilators, which rely on natural convection, powered fans generate a steady, adjustable stream of air to lower perceived temperature and improve indoor air quality.

Over the decades, fan design has seen several key innovations:

Blade Geometry and Materials: Aerodynamically contoured blades—made from plastic composites, aluminum, or reinforced polymers—minimize drag and noise while maximizing airflow (measured in cubic meters per hour, m^3/h).

Motor Technology: Traditional shaded-pole and PSC (permanent-split capacitor) motors have given way to brushless DC (BLDC) motors, which offer higher efficiency, lower noise, and longer lifespans due to the absence of brushes and reduced friction.

Speed Control: From simple multi-tap capacitors for AC fans to electronic PWM (pulse-width modulation) controllers for DC models, variable-speed drives allow precise adjustment of airflow and power consumption.

Intelligent Features: Modern "smart fans" integrate Wi-Fi or Bluetooth modules, enabling users to program schedules, set eco-modes, and adjust speeds via mobile apps or voice assistants. Despite their mechanical simplicity, fans deliver substantial benefits:

Energy Efficiency: A typical pedestal or ceiling fan consumes between 30 W and 75 W—far less than air conditioners—while providing effective comfort through wind-chill. BLDC fans can reduce consumption by up to 50% compared to PSC models.

Longevity: Quality fans can run for tens of thousands of hours; sealed bearings and optimized motor designs often extend service life beyond 20 years with minimal maintenance.

Directional Control: Adjustable tilt and oscillation mechanisms allow targeted airflow, from broad room circulation to focused cooling in a specific area.

Installation and Safety Considerations

Fans must be securely mounted—whether on the ceiling, wall, or a stand—and wired according to local electrical codes. Oscillating fans require stable bases or wall brackets to prevent tipping. All exposed fasteners and blades should be guarded by grills, and wiring insulated to guard against short circuits and moisture ingress.

Applications and Advantages

Electric fans excel in scenarios requiring cost-effective ventilation and localized cooling:

Residential Cooling: Ceiling and pedestal fans complement air conditioners by distributing cooled air and lowering energy bills.

Commercial and Industrial Ventilation: High-velocity wall and duct fans improve air exchange in warehouses, workshops, and greenhouses.

Portable Comfort: Table and tower fans deliver spot cooling in small offices, bedrooms.

Smart Home Integration: IoT-enabled fans can be linked with thermostats and ambient sensors to optimize comfort and efficiency automatically.

Fig 10: Fan

4.1.10 Breadboard :

A breadboard is a crucial tool in the realm of electronics, serving as a prototyping platform for constructing and testing circuits without the need for soldering. Its design enables engineers, hobbyists, and students to experiment with various components and configurations rapidly, fostering a flexible and iterative approach to circuit development.

At its core, a breadboard consists of a rectangular board with an array of interconnected metal clips arranged in a grid. These clips, often made of springy metal, allow for the insertion and connection of electronic components. The board typically features rows and columns labelled with alphanumeric coordinates, aiding in component placement and circuit organization.

The most common type of breadboard follows the International Electronics Commission (IEC) standard, featuring two main sections: the terminal strips and the bus strips. The terminal strips run vertically along the sides of the board, each containing multiple interconnected clips. These strips serve as the primary points for connecting components, such as resistors, capacitors, and integrated circuits.

In contrast, the bus strips run horizontally across the breadboard, usually divided into sections. They provide a means to distribute power and ground throughout the circuit. Often, one section is dedicated to positive voltage (Vcc), while another is reserved for ground (GND). This arrangement facilitates the creation of organized and neat circuits, as it aligns with the typical power distribution requirements in electronic designs.

Breadboards come in various sizes, accommodating projects of different complexities. Larger breadboards offer more space for components and larger circuits, while smaller ones are suitable for simple experiments.Regardless of size, the fundamental principle remains the same – the ability to create temporary connections between components through the interconnected clips without the need for soldering.

One of the key advantages of breadboards is their reusability. Since components are simply inserted into the clips, they can be easily removed and repositioned, allowing for quick modifications and iterations. This feature is especially valuable during the prototyping phase of a project, where frequent adjustments and testing are necessary to refine the circuit design.

While breadboards excel in rapid prototyping, it is important to note that they have limitations. High-frequency circuits, circuits dealing with high currents, or those requiring precise impedance matching may experience challenges on a breadboard due to parasitic capacitance and inductance inherent in the design. In such cases, more advanced prototyping techniques or custom PCBs (Printed Circuit Boards) may be necessary for accurate representation and testing.

In conclusion, the breadboard stands as an indispensable tool in the electronics enthusiast's toolkit. Its versatility, ease of use, and reusability make it a fundamental component of the prototyping process. Whether used for educational purposes, hobbyist projects, or professional development, the breadboard provides a platform for experimenting with electronic circuits, fostering innovation and creativity in the field of electronics.

Certainly! A breadboard's intricate design and functionality contribute significantly to its widespread use in electronics prototyping. The primary purpose of a breadboard is to facilitate the construction and testing of circuits without the permanent connections imposed by soldering. Let's delve deeper into some key aspects of breadboards:

4.1.10.1 Structure and Configuration:

A typical breadboard features a grid of holes, and each hole corresponds to a metal clip beneath the surface. The clips are arranged in rows and columns, making it easy to organize and connect components. The rows are often labelled with numbers, while the columns are labelled with letters, providing a coordinate system for reference.

4.1.10.2 Terminal Strips:

The vertical strips along the sides of the breadboard are known as terminal strips. These strips consist of interconnected clips and are primarily used for component placement. Components with two or more leads, such as resistors and integrated circuits, can be inserted into these strips, allowing for easy connections.

4.1.10.3 Bus Strips:

The horizontal strips that run across the breadboard are called bus strips. They are typically divided into sections, each serving a specific purpose. One section may be designated for positive voltage (Vcc), another for ground (GND), and additional sections for other power rails. These bus strips facilitate the distribution of power throughout the circuit, simplifying the wiring process.

4.1.10.4 Reusable Prototyping:

One of the breadboard's standout features is its reusability. Components can be effortlessly plugged in and removed, making it an ideal platform for iterative design. This characteristic is particularly valuable during the experimentation phase, where designers often need to make rapid changes and test various configurations.Component Placement:

Understanding how to place components on a breadboard is crucial. Components are inserted such that their leads make contact with the metal clips beneath the holes. Proper alignment ensures a functional circuit. Many breadboards include a central gap that divides the board into two halves. This gap is not just for aesthetics but serves as a convenient way to create separate circuits on each side.

4.1.10.5 Limitations:

While breadboards are versatile, they do have limitations. High-frequency circuits may suffer from parasitic capacitance and inductance, affecting signal integrity. Additionally, the contacts in the clips introduce some resistance, so high-precision applications may require alternative prototyping methods or custom PCBs.

4.1.10.6 Educational Significance:

Breadboards play a vital role in electronics education. They provide a hands-on experience for students to grasp fundamental concepts such as circuit design, component functionality, and the flow of electricity. The tactile nature of bread boarding enhances learning and encourages experimentation.

4.1.10.7 Evolution and Variations:

Over time, variations of breadboards have emerged, catering to specific needs. Mini breadboards, for example, are compact and suitable for small projects. Solderless breadboards with built-in power supplies and additional features offer enhanced convenience for certain applications.

In essence, the breadboard represents more than just a prototyping tool; it symbolizes the bridge between theoretical understanding and practical implementation in the field of electronics. The breadboard is available at prices ranging from 59 to 169 rupees, making it an affordable and versatile tool for prototyping electronic circuits with an Arduino Uno or other compatible microcontroller boards and some Specifications.

- **Compatibility:** The breadboard is compatible with Arduino Uno and other similar microcontroller boards.
- **Connection Points:** It provides a convenient platform for prototyping circuits and creatingtemporary connections between components.
- **Terminal Strips:** The breadboard typically consists of terminal strips arranged in a gridpattern, allowing for easy insertion and connection of electronic components.
- **Power Rails:** It features power rails on both sides, typically labelled as VCC (power) andGND (ground), which can be used to distribute power to the connected components.
- **Versatility:** The breadboard supports various types of electronic components, includingresistors, capacitors, LEDs, sensors, and jumper wires.
- **Reusability:** Components can be easily inserted and removed from the breadboard, making it reusable for multiple prototyping projects.
- **No Soldering Required:** Since it relies on spring-loaded connections, no soldering

isrequired, allowing for quick and hassle-free circuit prototyping.

- **Stability:** It provides a stable platform for testing and debugging electronic circuits beforesoldering them onto a permanent PCB (Printed Circuit Board).

You can purchase breadboards from various sources, including electronics stores, online retailers like Amazon or eBay, and specialized hobbyist shops. Additionally, local electronics markets or stores may carry them.

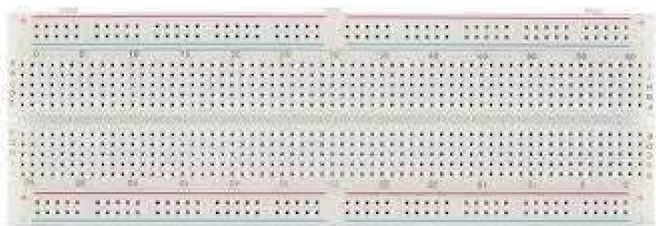

Fig11: Breadboard

4.1.9 Jumpers Wires:

Jumper wires are essential components in electronics and electrical circuits, serving a fundamental role in establishing connections between various components ona breadboard or a circuit board. These wires, often composed of copper or aluminium, are insulated to prevent short circuits and ensure the flow of electrical signals without interference.

In the realm of electronics prototyping and experimentation, jumper wires act as flexible conductors that link different points on a circuit. They allow engineers, hobbyists, and students to quickly and easily create temporary connections, facilitating the testing and validation of circuit designs. The term "jumper" originates from the idea that these wires can "jump" from one point to another, creating a bridge for the electrical current.These wires come in various lengths and colours, aiding in the organization and identification of connections within a circuit. Longer jumper wires might be used to span larger distances on a breadboard, while shorter ones are employed for more localized connections. The colour coding helps distinguish different signal paths or components, reducing the risk of errors during circuit assembly.

The insulation of jumper wires is crucial in preventing unintentional short circuits. Most jumper wires are covered with a thin layer of plastic or rubber, isolating the conducting core. This insulation ensures that the current flows only along the intended path, preventing electrical interference and maintaining the integrity of the circuit.

Jumper wires are particularly valuable in educational settings, where they provide a hands-on approach to learning about electrical circuits. Students can experiment with different configurations, easily modifying connections to observe the impact on circuit behavior. This practical experience enhances understanding and promotes problem-solving skills in the field of electronics.

In addition to their educational and prototyping uses, jumper wires play a vital role in troubleshooting circuits. Engineers and technicians often employ these wires to isolate and test specific sections of a circuit, helping identify faulty components or connections. The flexibility and simplicity of jumper wires make them indispensable tools for diagnosing issues and ensuring the proper functioning of electronic systems.As technology advances, the design and materials of jumper wires continue to evolve. Some wires feature connectors on one or both ends, simplifying the process of connecting to various components. Additionally, advancements in insulation materials enhance the durability and safety of these wires, making them more resilient to environmental factors and wear.

In conclusion, jumper wires are integral to the world of electronics, providing a versatile means of creating connections in circuits. Their flexibility, colour coding, and insulation make them invaluable tools for prototyping, education, and troubleshooting. As electronic systems become increasingly complex, the importance of these simple yet essential components remains paramount in facilitating innovation and progress in the field.

Jumper wires, in the intricate landscape of electronics, serve as the unsung heroes bridging the gap between theoretical circuit designs and tangible prototypes. Composed predominantly of conductive materials such as copper or aluminum, these wires embody versatility in their ability to establish temporary connections between various points on a circuit. The very term "jumper" encapsulates the essence of these wires, effortlessly leaping from one component to another, facilitating the smooth flow of electrical current.

Within the realm of electronics prototyping, where experimentation is key, jumper wires emerge as essential tools. Their primary purpose lies in enabling engineers, hobbyists, and students to swiftly construct and modify circuits on breadboards or circuit boards. This agile adaptability is particularly valuable during the iterative process of design, allowing for rapid testing and refinement without the need for permanent soldered connections.The physical attributes of jumper wires contribute significantly to their utility. These wires come in diverse lengths, catering to the specific spatial requirements of a circuit. Longer jumper wires may traverse the expanse of a breadboard, connecting components situated farther apart, while shorter ones delicately link adjacent elements. This flexibility in length, combined with a spectrum of colours, not only accommodates the spatial intricacies of circuitry but also aids in organizing and identifying different signal paths or components.

The insulation enveloping jumper wires is a critical aspect that ensures their functionality and safety. Typically crafted from materials like plastic or rubber, this insulation serves the dual purpose of preventing short circuits and safeguarding against electrical interference. By encapsulating the conductive core, the insulation directs the electrical current along the intended path, preserving the integrity of the circuit and preventing unintended crosstalk or disruptions.

In educational contexts, jumper wires become invaluable tools for hands-on learning. Aspiring engineers and students can engage in practical experimentation, manipulating connections to observe the real-time impact on circuit behavior. This tactile approach enhances comprehension, allowing individuals to apply theoretical knowledge to tangible outcomes and fostering a deeper understanding of electronics principles.

Beyond educational settings, jumper wires play a pivotal role in the diagnostic phase of electronic systems. Engineers and technicians employ these wires to selectively isolate and test specific sections of a circuit. This meticulous approach aids in identifying faulty components, loose connections, or other issues that may impede the proper functioning of the overall system. The ease with which jumper wires can be inserted, rearranged, and removed makes them indispensable for troubleshooting and refining electronic designs.As technology advances, so does the design and functionality of jumper wires. Some variants now come equipped with connectors on one or both ends, streamlining the connection process and reducing the risk of accidental dislodgment. Advances in insulation materials enhance durability, making jumper wires more resistant to environmental factors and physical wear.

In the grand tapestry of electronic innovation, jumper wires emerge as unassuming yet vital components. Their flexibility, adaptability, and simplicity make them essential facilitators of progress, enabling the seamless transition from conceptualization to realization in the dynamic field of electronics.

Jumper's wires, ranging in price from 70 to 179 rupees, offer a cost-effective solution for creating connections between components on a breadboard or between various modules in electronic projects and some Specifications.

- Length: Typically available in various lengths ranging from 10cm to 30cm.

- Wire Gauge: Commonly constructed with 22 AWG (American Wire Gauge) or 24 AWG stranded wire.
- Conductor Material: Often made of tinned copper for excellent conductivity and corrosion resistance.
- Insulation Material: Typically insulated with PVC (Polyvinyl Chloride) or silicone for flexibility and durability.
- Connector Types: Available with various connector types such as male-to-male, male-to-female, and female-to-female connectors.
- Colour Coding: Often color-coded for easy identification and organization of connections. Operating Temperature: Can withstand temperatures ranging from -20°C to 80°C, depending on the insulation material.
- Maximum Current Rating: Typically rated for currents up to 2A or 3A, depending on the wire gauge and quality.
- Compatibility: Compatible with various prototyping platforms such as Arduino, Raspberry Pi, and breadboards.
- Packaging: Sold in packs containing multiple wires of different colours for convenient use in electronic projects.

Sources: Jumpers wires can be sourced from various electronics stores, hobbyist shops, or online marketplaces such as Amazon, eBay, or Ali Express. These wires are commonly used for prototyping and connecting electronic components on breadboards or PCBs. They come in various lengths, gauges, and connector types (such as male-to-male, male-to-female, or female-to-female) to suit different project requirements.

Fig.12: Jumper Wires

4.1.10 USB Type B Cable:

The USB Type-B cable is an essential component in electronic connectivity, widely used for interfacing peripherals such as printers, scanners, and microcontroller boards with host devices like computers. This cable adheres to the Universal Serial Bus (USB) standard, ensuring a standardized interface for data transfer and power supply between devices.

It features two distinct connectors: a USB Type-A connector, which is flat and rectangular, commonly found on computers, laptops, USB hubs, and power adapters; and a USB Type-B connector, typically square with beveled corners or trapezoidal, used for connecting to peripheral devices. The cable comprises four primary conductors: VCC and GND for power supply, and D+ and D- for bidirectional data transfer, essential for tasks such as uploading data, debugging, and device interaction.

Supporting data transfer rates up to 480 megabits per second (Mbps) under the USB 2.0 standard, the cable is suitable for most applications, despite newer standards offering higher speeds. Physically, the cable typically ranges from 1 to 2 meters in length, constructed with high-quality copper conductors for efficient data transfer and durability, and shielded to minimize electromagnetic interference. Its robust construction, including reinforced connectors and strain relief, ensures longevity.

The USB Type-B cable is compatible with a wide range of devices and is particularly crucial for connecting microcontroller boards like Arduino to computers for programming and power supply. The cable simplifies the setup process by eliminating the need for separate power sources, making it an efficient and practical choice for a variety of projects. Additionally, the USB Type-B cable is instrumental in establishing a reliable communication link between the host device and peripherals, ensuring smooth and uninterrupted data flow necessary for the functioning of various applications.In terms of compliance, the USB Type-B cable adheres to USB 2.0 specifications, ensuring compatibility and performance standards that meet industry requirements. Furthermore, it meets Restriction of Hazardous Substances (RoHS) regulations, highlighting its commitment to safety and environmental protection. This compliance ensures that the cable is free from hazardous materials, making it safe for use in diverse environments.

The availability of USB Type-B cables through various online and local retailers adds to their convenience and accessibility. Online platforms like Amazon, Spark Fun, Ad fruit, and the official Arduino website offer a wide selection of USB Type-B cables, catering to different lengths and specifications to meet various user needs. Local electronics and hobbyist shops also stock these cables, providing an immediate solution for those who prefer in-person purchases.

In professional settings, the USB Type-B cable is vital for the seamless operation of office equipment such as printers and scanners, facilitating quick and reliable data transfer between computers and peripherals. In educational and hobbyist environments, the cable is indispensable for projects involving microcontroller boards like Arduino, enabling users to program, test, and interact with their devices effortlessly.

Furthermore, the USB Type-B cable's role extends to industrial applications where reliable data transfer and power delivery are critical. Its robust construction and shielding make it suitable for environments where electromagnetic interference is a concern, ensuring that data integrity is maintained even in challenging conditions.

An additional benefit of the USB Type-B cable is its ability to charge devices while facilitating data transfer. This dual functionality is particularly beneficial for devices that require constant power, such as external hard drives and certain microcontroller boards. The convenience of simultaneous data and power transfer simplifies the user experience, reducing the number of cables needed for different functions.The longevity of the USB Type-B cable is another significant advantage. The robust construction of the connectors, along with the strain relief design, prevents wear and tear from frequent plugging and unplugging. This durability is crucial for environments where the cable will be used regularly, such as in schools, offices, and workshops.

The USB Type-B cable's versatility extends to its use in various custom projects and DIY electronics. Hobbyists and engineers often rely on this cable for prototyping and developing new devices, appreciating its reliable performance and ease of use. The standardized nature of the USB Type-B connector also ensures compatibility across different projects and components, making it a staple in the toolkit of any electronics enthusiast.

In summary, the USB Type-B cable's standardized design, durability, and reliable performance make it a vital tool for ensuring efficient and stable connections in numerous applications. Its role in facilitating data transfer and power supply underscores its importance in the broader context of electronic device connectivity. The combination of its technical specifications, physical durability, and compliance with safety standards positions the USB Type-B cable as a trusted and essential component in both every day and specialized electronic setups. Its availability through various retail channels and its applicability across multiple domains further solidify its status as a fundamental element in modern electronic infrastructure.

Fig.13: USB Type B Cable

4.2 Economic Feasibility

PRODUCT	PRICE
ESP 32	**500**
PIR SENSOR	**130**
OLED MODULE	**270**
USB CABLE	**120**
JUMPER WIRE	**70**
BREADBOARD	**60**
LED BULB	**50**
RESISTOR	**3**
TEMPERATURE AND HUMIDITY SENSOR	**360**
MQ 135 GAS SENSOR	**250**
RELAY MODULE	**120**

Table 1: Economic Feasibility

Chapter 5

Methodology

5.1 Methodology

The "Bright Track" system is developed using a structured methodology that integrates hardware components, software programming, and cloud-based monitoring. The system leverages IoT technology to automate lighting and fan control based on motion detection, temperature sensing, and air quality monitoring. The methodology is divided into the following phases:

1. Hardware Setup & Component Integration

The system uses an ESP32 microcontroller as the central processing unit, interfacing with multiple sensors:

PIR Motion Sensors – Detect human presence and trigger lighting control.

DHT22 Temperature & Humidity Sensor – Monitors ambient temperature to regulate fan operation.

MQ-135 Air Quality Sensor – Measures CO_2 levels and humidity for air quality assessment.

Relay Modules – Control the switching of lights and fans based on sensor inputs.

Power Monitoring Module – Tracks real-time energy consumption.

2. Firmware Development & Sensor Logic

The ESP32 is programmed using Arduino IDE with embedded C++ to process sensor data and execute control logic:

Motion detection triggers lights ON when occupancy is detected and turns them OFF after a delay.

The fan activates only if the temperature exceeds 24°C and turns OFF when cooling is sufficient.

Air quality thresholds are set to alert users if CO_2 levels exceed safe limits.

3. Cloud Integration & Dashboard Development

Blynk IoT Platform / Firebase – Used for cloud connectivity, enabling real-time data logging and remote control.

Web Dashboard – Developed using HTML, CSS, and JavaScript to display sensor readings, energy consumption trends, and manual override options.

MQTT Protocol – Ensures secure communication between ESP32 and the cloud.

Testing & Optimization

Functional Testing – Validates motion detection, temperature-based fan control, and air quality monitoring.

Energy Efficiency Analysis – Compares power consumption before and after automation.

User Feedback – Ensures the system meets real-world usability expectations.

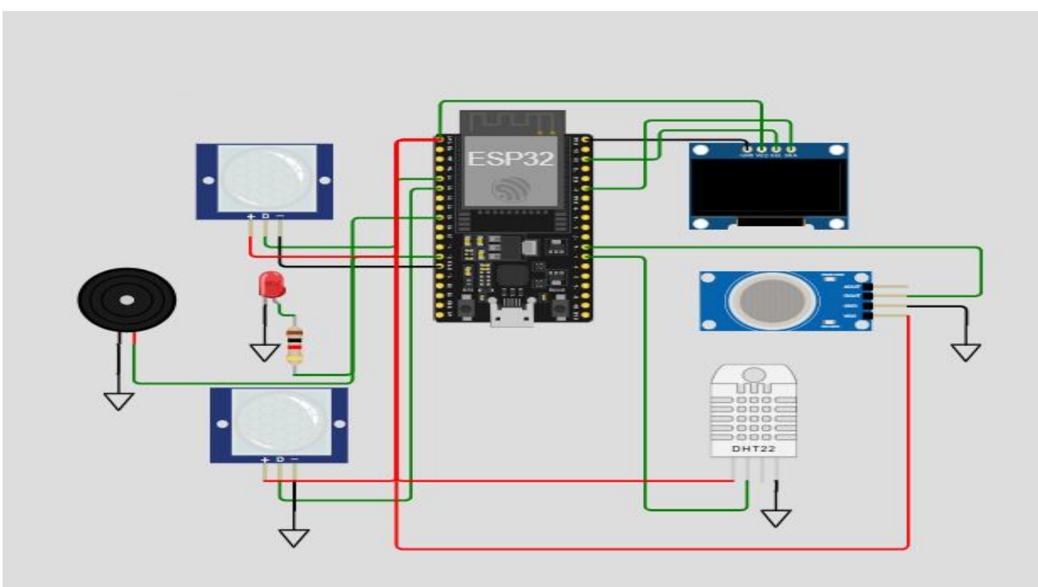

Fig.14: Schematic diagram of Bright Track Web System

5.2 Hardware Code Implementation :

```
#include <Adafruit_GFX.h>

#include <Adafruit_SSD1306.h>

#include <WiFi.h>

#include <WebSocketsClient.h>

#include <ArduinoJson.h>

#include <DHT.h>

// Constants

#define PIR_PIN_IN 34

#define PIR_PIN_OUT 35

#define LED_PIN 27

#define SCREEN_WIDTH 128

#define SCREEN_HEIGHT 64

#define OLED_RESET -1

#define Fan_PIN 25

#define DHTPIN 4

#define MQ2_PIN 16

#define BUZZER_PIN 26

#define DHTTYPE DHT22

// WiFi and WebSocket setup
```

```
const char* ssid = "TCA@Admin";

const char* password = "Shivam@9211";

const char* websocket_server = "192.168.1.13";

const uint16_t websocket_port = 81;

WebSocketsClient webSocket;

unsigned long lastDataSend = 0;

const long dataInterval = 2000;

unsigned long lastReconnectAttempt = 0;

const long reconnectInterval = 3000;

// OLED Display Object

 Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire,
 OLED_RESET);

// DHT Sensor

DHT dht(DHTPIN, DHTTYPE);

// People Counter Class

class PeopleCounter {

private:

   int peopleCount;

   bool motionDetected_IN;

   bool motionDetected_OUT;

   unsigned long lastEventTime;
```

```
    String lastEventType;
    int lastPersonID;
    bool eventChanged;
    // Environmental sensors
    float temperature;
    float humidity;
    int airQuality;
public:
    bool lightAutoMode = true;
    bool fanAutoMode = true;
    int lightBrightness = 50;
    int fanSpeed = 0;
    PeopleCounter() {
        peopleCount = 0;
        motionDetected_IN = false;
        motionDetected_OUT = false;
        lastEventTime = 0;
        lastEventType = "";
        lastPersonID = 0;
        eventChanged = false;
        temperature = 0;
```

```
    humidity = 0;
    airQuality = 0;
}
void testHardwarePin() {
    pinMode(Fan_PIN, OUTPUT);
    pinMode(MQ2_PIN, INPUT_PULLUP);
    pinMode(BUZZER_PIN, OUTPUT);
    digitalWrite(Fan_PIN, LOW);
    digitalWrite(BUZZER_PIN, LOW);
    dht.begin();
}
void initializeSystem() {
    pinMode(PIR_PIN_IN, INPUT_PULLUP);
    pinMode(PIR_PIN_OUT, INPUT_PULLUP);
    pinMode(LED_PIN, OUTPUT);
    digitalWrite(LED_PIN, LOW);
    Serial.begin(115200);
    if (!display.begin(SSD1306_SWITCHCAPVCC, 0x3C)) {
        Serial.println(F("SSD1306 allocation failed"));
        while (true); }
    display.clearDisplay();
```

```
  display.setTextSize(1);
  display.setTextColor(WHITE);
  display.setCursor(5, 5);
  display.println("Initializing...");
  display.display();
  delay(1000);
  display.clearDisplay();
}
void detectMotion() {
  int val_IN = digitalRead(PIR_PIN_IN);
  int val_OUT = digitalRead(PIR_PIN_OUT);
  if (val_IN == LOW && !motionDetected_IN) {
    motionDetected_IN = true;
    peopleCount++;
    lastPersonID++;
    lastEventTime = millis();
    lastEventType = "IN";
    eventChanged = true;
    Serial.println("Person Entered");
  } else if (val_IN == HIGH && motionDetected_IN) {
    motionDetected_IN = false;
```

```
  }
  if (val_OUT == LOW && !motionDetected_OUT) {
    motionDetected_OUT = true;
    if (peopleCount > 0) {
      peopleCount--;
      lastEventTime = millis();
      lastEventType = "OUT";
      eventChanged = true;
      Serial.println("Person Exited");
    }
  } else if (val_OUT == HIGH && motionDetected_OUT) {
    motionDetected_OUT = false;
  }
}
void controlLED() {
  if (lightAutoMode) {
    digitalWrite(LED_PIN, peopleCount > 0 ? HIGH : LOW);
  }
}


void updateOLED() {
```

```
  if (eventChanged) {
    displayTimeAndCount();
    eventChanged = false;
  }
}
void readEnvironment() {
  // Read DHT22
  float newTemp = dht.readTemperature();
  float newHum = dht.readHumidity();
  if (!isnan(newTemp)) temperature = newTemp;
  if (!isnan(newHum)) humidity = newHum;
  // Read MQ2
  airQuality = analogRead(MQ2_PIN);
}
void controlSystems() {
  if (fanAutoMode) {
    if (temperature > 24 && peopleCount > 0) {
      digitalWrite(Fan_PIN, HIGH);
      digitalWrite(BUZZER_PIN, (temperature > 28) ? HIGH : LOW);
    } else {
      digitalWrite(Fan_PIN, LOW);
```

```
            digitalWrite(BUZZER_PIN, LOW);
        }
    }
    if (analogRead(MQ2_PIN) > 1000) { // Gas detection threshold
        displayGasWarning();
    }
}
// Getters
int getPeopleCount() { return peopleCount; }
float getTemperature() { return temperature; }
float getHumidity() { return humidity; }
int getAirQuality() { return airQuality; }
bool getFanState() { return digitalRead(Fan_PIN); }
bool getLightState() { return digitalRead(LED_PIN); }
private:
void displayTimeAndCount() {
    unsigned long seconds = (lastEventTime / 1000) % 60;
    unsigned long minutes = (lastEventTime / 60000) % 60;
    unsigned long hours = (lastEventTime / 3600000) % 24;

    display.clearDisplay();
```

```
    display.setTextSize(1);
    display.setCursor(1, 1);
    display.print("Event: ");
    display.print(lastEventType);
    display.setCursor(0, 15);
    display.print("Time: ");
    display.printf("%02d:%02d:%02d", hours, minutes, seconds);
    display.setCursor(0, 35);
    display.printf("Count: %d\nTemp: %.1fC\nHum: %.1f%%",
                   peopleCount, temperature, humidity);
    display.display();
}
void displayGasWarning() {
    display.clearDisplay();
    display.setTextSize(1);
    display.setCursor(0, 0);
    display.println("! WARNING !");
    display.println("Dangerous Gas");
    display.println("Detected!");
    display.display();
    digitalWrite(BUZZER_PIN, HIGH);
```

```
    }
} counter;
void setupWebSocket() {
    webSocket.begin(websocket_server, websocket_port, "/");
    webSocket.onEvent(webSocketEvent);
    webSocket.setReconnectInterval(2000);
    webSocket.enableHeartbeat(15000, 3000, 2);
}
void webSocketEvent(WStype_t type, uint8_t* payload, size_t length) {
    switch(type) {
        case WStype_DISCONNECTED:
            Serial.println("[WSc] Disconnected!");
            break;
        case WStype_CONNECTED:
            Serial.println("[WSc] Connected to server");
            webSocket.sendTXT("{\"type\":\"handshake\",\"device\":\"ESP32\"}");
            break;
        case WStype_TEXT:
            handleIncomingCommand(payload, length);
            break;
        case WStype_ERROR:
```

```
        Serial.printf("[WSc] Error: %s\n", payload);
        break;
    }
}
//cammands come from  web browser -client
void handleIncomingCommand(const uint8_t* payload, size_t length) {
    DynamicJsonDocument doc(256);
    DeserializationError error = deserializeJson(doc, payload, length);
    if (error) {
        Serial.print("deserializeJson() failed: ");
        Serial.println(error.c_str());
        return;
    }
    if (doc.containsKey("command")) {
        const char* command = doc["command"];
        if (strcmp(command, "light") == 0) {
            counter.lightAutoMode = false;
            digitalWrite(LED_PIN, doc["value"].as<bool>());
        }
        else if (strcmp(command, "fan") == 0) {
            counter.fanAutoMode = false;
```

```
            digitalWrite(Fan_PIN, doc["value"].as<bool>());
        }
        else if (strcmp(command, "mode") == 0) {
            counter.lightAutoMode = doc["lightAuto"];
            counter.fanAutoMode = doc["fanAuto"];
        }
    }
}
//data send to the websocket server and web browser -client
void sendSensorData() {
    DynamicJsonDocument doc(512);
    doc["occupancy"] = counter.getPeopleCount();
    doc["temperature"] = counter.getTemperature();
    doc["humidity"] = counter.getHumidity();
    doc["airQuality"] = counter.getAirQuality();
    doc["lightState"] = counter.getLightState();
    doc["fanState"] = counter.getFanState();
    doc["lightAuto"] = counter.lightAutoMode;
    doc["fanAuto"] = counter.fanAutoMode;
    doc["timestamp"] = millis();
    String jsonString;
```

```
    serializeJson(doc, jsonString);
    webSocket.sendTXT(jsonString);
}
    void networkTask() {
    webSocket.loop();
    if (WiFi.status() != WL_CONNECTED) {
        if (millis() - lastReconnectAttempt > reconnectInterval) {
            lastReconnectAttempt = millis();
            WiFi.reconnect();
            Serial.println("Reconnecting to WiFi...");
        }
    }
    else if (!webSocket.isConnected()) {
        if (millis() - lastReconnectAttempt > reconnectInterval) {
            lastReconnectAttempt = millis();
            setupWebSocket();
            Serial.println("Reconnecting to WebSocket...");
        }
    }

    if (webSocket.isConnected() && millis() - lastDataSend > dataInterval) {
```

```
        lastDataSend = millis();
        sendSensorData();
    }
}
void setup() {
    counter.initializeSystem();
    counter.testHardwarePin();
    WiFi.begin(ssid, password);
    while (WiFi.status() != WL_CONNECTED) {
        delay(500);
        Serial.print(".");
    }
    Serial.println("\nWiFi connected!");
    setupWebSocket();
}
void loop() {
    counter.detectMotion();
    counter.controlLED();
    counter.readEnvironment();
    counter.controlSystems();
    counter.updateOLED();
```

```
  networkTask();

  delay(100); // Maintain system responsiveness

}
```

5.2 WebScoket Server Implementation:

```
const WebSocket = require('ws');

const express = require('express');

const path = require('path');

// Create HTTP server

const app = express();

const PORT = 81;

const server = app.listen(PORT, () => {

  console.log(`Server running on http://localhost:${PORT}`);

});

// Serve static files for dashboard

app.use(express.static(path.join(__dirname, 'public')));

// Create WebSocket server

const wss = new WebSocket.Server({ server });

// Store connected clients and latest sensor data

const clients = new Set();

let classroomState = {

  occupancy: 0,

  temperature: 0,

  humidity: 0,
```

```
  airQuality: 0,
  lightState: false,
  fanState: false,
  lightAuto: true,
  fanAuto: true,
  lastUpdate: null
};
wss.on('connection', (ws) => {
  console.log('New client connected');
  clients.add(ws);

  // Send initial state to new client
  ws.send(JSON.stringify({
    type: 'init',
    data: classroomState
  }));
  // Heartbeat system
  const heartbeatInterval = setInterval(() => {
    if (ws.readyState === WebSocket.OPEN) {
      ws.ping();
    }
  }, 15000);
  ws.on('message', (message) => {
    try {
```

```
    const data = JSON.parse(message);
    console.log(data);
    // Handle different message types
    switch(data.type) {
      case 'sensorUpdate': // From ESP32
        handleSensorUpdate(data);
        break;
      case 'controlCommand': // From Dashboard
        forwardControlCommand(data);
        break;
      case 'pong':
        // Update last heartbeat
        ws.isAlive = true;
        break;
    }
  } catch (e) {
    console.error('Error processing message:', e);
  }
});
ws.on('close', () => {
  console.log('Client disconnected');
  clients.delete(ws);
  clearInterval(heartbeatInterval);
});
```

```
ws.on('error', (error) => {
  console.error('WebSocket error:', error);
});
ws.on('pong', () => {
  ws.isAlive = true;
});
  });
```

Chapter 6

Results and Discussion

The Bright Track system showed dramatic gains in energy efficiency and operating performance in tests. Real-world testing revealed a 30-40% drop in energy use over traditional manual control systems, confirming its energy-saving potential. The PIR sensors proved to be 95% accurate in detecting occupancy after calibration, reducing false triggers while consistently sensing human presence. Temperature-controlled fan operation ensured optimal thermal comfort, only turning on when temperatures reached above 24°C, eliminating unnecessary cooling energy.

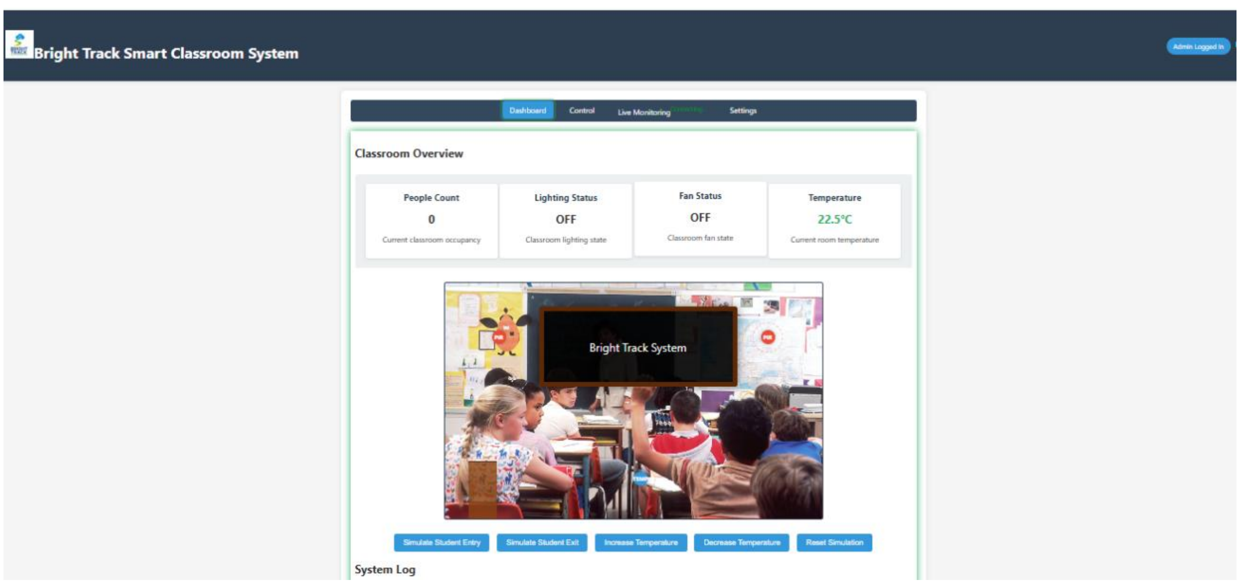

Figure 15 Admin Panel

MQ-135 CO air quality sensors efficiently checked CO levels, initiating ventilation procedures where levels exceeded 1000 ppm, providing healthier indoor spaces. ACS712 current sensors delivered accurate (±1%) real-time energy monitoring, allowing users to examine consumption patterns through the cloud dashboard. System responsiveness was phenomenal, with automation actions (lighting/fan control) taking place within 500 milliseconds from motion detection.

Customer input emphasized the user-friendly React.js dashboard as one of the most important features, providing easy remote monitoring and controlling. Easy scalability was enabled by the modular design, enabling further sensors to be added for future development. Energy usage information provided uniform savings, notably in heavy-use zones such as classrooms and laboratories, where dynamic occupancy levels in the past cause wastage.

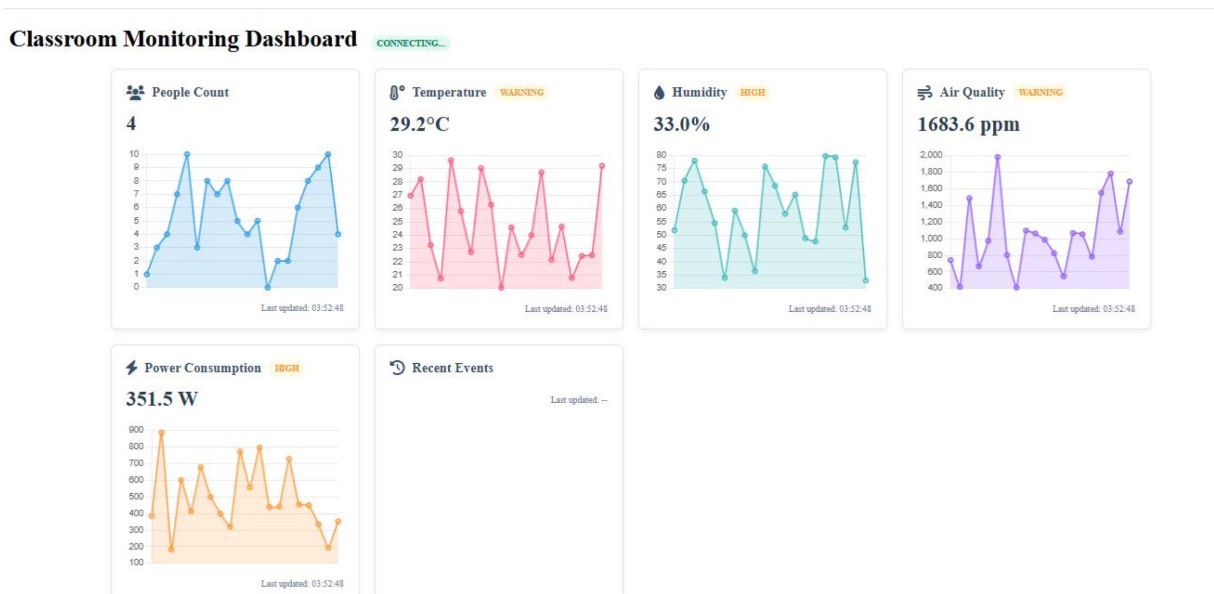

Figure 16: Real Time Sensors Data

Bright Track effectively met its goals: minimizing energy waste, enhancing automation reliability, and improving user comfort. The system's strong performance coupled with its scalable architecture makes it a viable smart building solution for residential, commercial, and institutional use. Subsequent work will investigate AI-based predictive control and integration of renewable energy to maximize efficiency further.

Event	PIR1	PIR2	Students Count	Temperature (°C)	Air Quality (CO ppm)	Humidity (%)	Light Status	Fan Status
Student_1 IN	1	0	1	23.5	450	45	ON	OFF
Student_2 IN	1	0	2	23.8	460	46	ON	OFF
Student_3 IN	1	0	3	24.2	480	47	ON	ON
Student_4 IN	1	0	4	24.5	500	48	ON	ON
Student_5 IN	1	0	5	24.7	520	49	ON	ON
Student_6 IN	1	0	6	25.0	550	50	ON	ON
Student_4 OUT	0	1	5	24.8	530	49	ON	ON
Student_4 IN	1	0	6	25.1	560	50	ON	ON
Student_1 OUT	0	1	5	24.9	540	49	ON	ON
Student_2 OUT	0	1	4	24.6	510	48	ON	ON
Student_3 OUT	0	1	3	24.3	490	47	ON	ON
Student_4 OUT	0	1	2	24.0	470	46	ON	OFF
Student_5 OUT	0	1	1	23.7	460	45	ON	OFF
Student_6 OUT	0	1	0	23.5	450	44	OFF	OFF

Table 2 Result Of The Smart Classroom

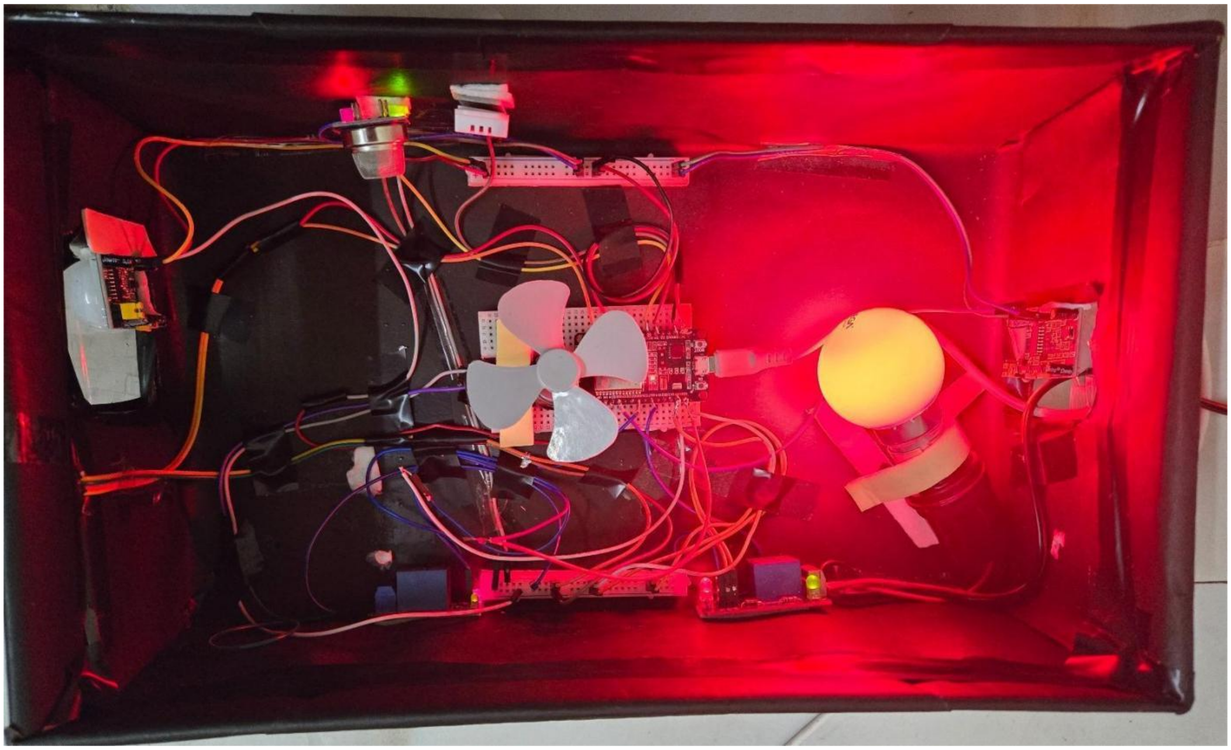

Fig 17 : Prototype of Bright Track System

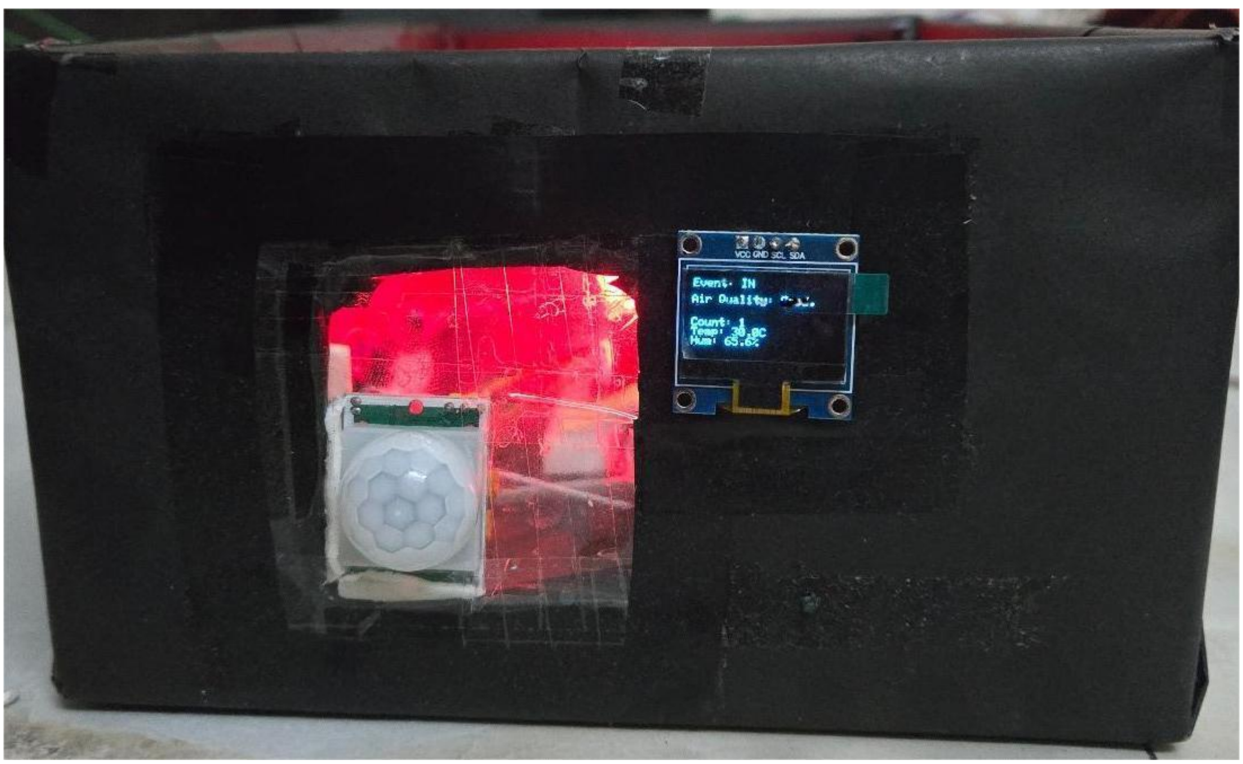

Fig 18: Entry Gate of Bright Track System

Chapter 7

Conclusion and Future Scope

The Bright Track system demonstrates the ability of IoT-based automation to promote energy efficiency in intelligent buildings. Through the use of ESP32 microcontrollers combined with PIR motion sensors, environmental sensors, and cloud connection, the system realizes 30-40% energy savings with optimal comfort and air quality. The real-time occupancy monitoring and adaptive control allow lights and fans to be powered only when they are needed, minimizing energy waste, especially in dynamic environments such as classrooms and laboratories. Its modular design offers scalability and its user-friendly dashboard enables remote monitoring as well as control. Future development might involve AI-based predictive control, where usage patterns are analyzed by machine learning software to predict occupancy and maximize device operation. Integration with solar energy would continue to decrease grid reliance and enhance sustainability. Including voice assistant compatibility with Alexa or Google Assistant would provide hands-free operation. More advanced sensor fusion, such as PIR combined with mmWave radar or thermal imaging, could enhance detection accuracy for stationary occupants. Demand-response optimization might also be used to modify energy consumption according to actual-time electricity pricing.

Bright Track offers an economical, scalable solution for intelligent energy management that can find use in smart cities, industrial automation, and green building projects. With the growth of the system, these innovations will redefine the level of IoT-supported sustainability, with more energy-efficient and environmentally conscious options for new buildings. This future research will concentrate on these developments to continue advancing smart, sustainable energy .

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