PROJECT REPORT

On

"Intelligent Home Automation System Using Gen AI and IoT for Personalized Energy Management to Reduce Carbon Footprint"

Submitted By

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Submitted in partial fulfillment of the requirements
for
Degree of Bachelor of Technology

Guided By,

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DEPARTMENT OF EMERGING TECHNOLOGIES (AI&ML)

S. B. JAIN INSTITUTE OF TECHNOLOGY, MANAGEMENT & RESEARCH, NAGPUR

(An Autonomous Institute, Affiliated to RTMNU, Nagpur)

2024-2025

❖ Institute Vision:

- Emerge as a leading Institute for developing competent and creative Professionals.

❖ Institute Mission:

- Providing Quality Infrastructure and experienced faculty for academic excellence.
- Inculcating skills, knowledge and opportunities for competency and creativity.
- Aligning with Industries for knowledge sharing, research and development.

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- To create competent and creative professionals in the field of Artificial Intelligence & Machine Learning to address the needs of industry and society.

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- Have strong work ethics and professionalism, reflected through communication skills, leadership, teamwork and sense of responsibility towards the society.
- Be successful professionals through lifelong learning with allied objectives of higher education or research.

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SESSION 2024-2025

CERTIFICATE

This is to certify that the Project Report titled **"Intelligent Home Automation System Using Gen AI and IoT for Personalized Energy Management to Reduce Carbon Footprint"** submitted by **Ms. Vaishnavi Rahamatkar, Mr. Atharva Wakdikar, Mr. Ayush Roy, Ms. Vaishnavi Dhekwar** has been accepted under the guidance of **Mr. Yogesh Narekar.** This Project work is carried out for the partial fulfillment of "**PROJECT–I (PROJAM702)"** of VII Semester of Bachelor of Technology in **Artificial Intelligence and Machine Learning, S. B. Jain Institute of Technology, Management & Research, An Autonomous Institute, Affiliated to RTMNU, Nagpur.**

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Dr. Hemant Turkar
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Dr. S. L. Badjate
Principal

<u>DECLARATION</u>

We hereby declare that the Project Report titled **"Intelligent Home Automation System Using Gen AI and IoT for Personalized Energy Management to Reduce Carbon Footprint"** submitted herein has been carried out by us in the Department of Emerging Technology (AI&ML) of S. B.Jain Institute of Technology, Management and Research, Nagpur under the guidance of **Mr. Yogesh Narekar.** The work is original and has not been submitted earlier as a whole or in part for the award of any degree/diploma at this or any other Institution/University.

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Date: - / /

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ABSTRACT

The Intelligent Home Automation System that integrates Generative AI and the Internet of Things (IoT) represents a cutting-edge approach to personalized energy management. This system enables homeowners to optimize energy consumption through real-time monitoring and intelligent automation. By connecting smart devices—such as thermostats, lighting, and appliances—these systems can analyze usage patterns and environmental data to provide tailored recommendations. The use of Generative AI enhances this functionality by predicting energy needs and adapting settings to maximize efficiency. This not only helps reduce energy bills but also significantly lowers the carbon footprint of households, contributing to a more sustainable environment. This paper explores the development and implementation of an Intelligent Home Automation System that leverages Generative AI and the Internet of Things (IoT) to enhance personalized energy management and reduce carbon footprints. As energy consumption patterns evolve, integrating smart technologies allows homeowners to optimize energy usage dynamically. The system utilizes IoT devices to collect real-time data on energy consumption, environmental conditions, and user behavior, while Generative AI analyzes this data to provide actionable insights and personalized recommendations. By automating energy management processes such as adjusting heating, cooling, and lighting based on occupancy and preferences this intelligent system not only enhances energy efficiency but also lowers operational costs. Furthermore, it fosters sustainable living by encouraging eco-friendly habits. The findings indicate that such a system can lead to significant reductions in energy waste and greenhouse gas emissions, offering a viable pathway for households to contribute to environmental sustainability in an increasingly energy-conscious world.

Keywords/Index Terms*— Thingspeak, virtual interior, Automation,* visualizations, *real time, less efforts etc .*

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ABBREVIATION

ABBREVIATION	FULL FORM
IOT	Internet Of Things

LIST OF PUBLICATION / PARTICIPATION/COPYRIGHT

Sr. No	Title	Event Name / Journal Name/ Conference/ Diary No. of Copyright Publication	Date	Remark
1	Development of Web Application for Managing Tourism	TECHNOTHON 2023 College Name/ Nagpur/Diary No-7418/2023-CO/L	29 NOV 2023	Project Competition/ Applied for copyright
2	Development of Web Application for Managing Tourism	Conference Details /Journal Details	29 NOV 2023	Paper Published/ Accepted/ Presented

CHAPTER NO. 1

INTRODUCTION

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1.1 PROJECT BACKGROUND

In recent years, there has been a growing need for smarter and more sustainable living solutions. Energy consumption, particularly in households, is a major contributor to environmental degradation and high energy costs. As the global population increases and urbanization accelerates, managing energy resources efficiently and minimizing their environmental impact have become top priorities. Home automation systems have evolved significantly, and with the advent of IoT (Internet of Things) and Generative AI, there is now an opportunity to create a personalized and intelligent home environment that optimizes energy use while reducing carbon footprints. Generative AI, in combination with IoT devices, can make real-time decisions based on data from various sensors and external environmental factors to control energy use in homes more effectively. The proposed system aims to harness the potential of these technologies to create a smart home automation solution that adapts to the habits of the residents, manages energy consumption intelligently, and provides insights to help reduce carbon emissions.

1.2 PROBLEM STATEMENT

The problem lies in the inefficient and often wasteful use of energy in households. Current home automation systems typically lack the level of intelligence required to optimize energy management fully. While there are devices like smart thermostats, lighting systems, and appliances that can be controlled remotely, they do not automatically adjust based on usage patterns or external factors such as weather conditions or electricity pricing. Additionally, most existing systems do not provide meaningful insights to homeowners on how to reduce their energy consumption or carbon footprint. This results in higher energy bills, inefficient energy use, and an overall greater environmental impact. The challenge, therefore, is to design a system that integrates IoT devices with Generative AI algorithms to predict, control, and optimize energy consumption in a way that is adaptive, efficient, and environmentally responsible.

1.3 PURPOSE OF STUDY

The purpose of this study is to investigate and develop an Intelligent Home Automation System that utilizes the capabilities of Generative AI and IoT to manage energy use more efficiently. Specifically, this system aims to:

- **Optimize Energy Consumption**: By learning user habits and environmental factors, the system will automatically adjust settings for heating, cooling, lighting, and appliances to ensure energy is used efficiently.

- **Reduce Household Carbon Footprint**: Through optimized energy management, the system will minimize unnecessary energy use, reducing the overall carbon footprint of the household.

- **Provide Personalized Insights**: The system will offer insights into the household's energy usage patterns, offering recommendations for further reducing energy consumption and adopting more sustainable practices.

- **Enable Predictive Energy Management**: Using AI to predict and adjust energy use based on factors such as weather, time of day, or individual routines, the system will provide a proactive rather than reactive solution.

By conducting this study, the aim is to provide an innovative, scalable, and sustainable solution for modern households, aligning with the global push for energy efficiency and environmental sustainability.

AIM:-The aim of the project is to develop an Intelligent Home Automation System that uses Generative AI and IoT to optimize personalized energy management and reduce household carbon footprints.

OBJECTIVE

- Implement IoT-enabled sensors and devices to continuously monitor energy consumption patterns and environmental conditions within the home.
- Design and integrate automated controls that adjust energy settings in real time, ensuring maximum efficiency without compromising comfort.
- Design the system to be scalable and adaptable to different household sizes and types, ensuring broad applicability and ease of implementation.
- Develop a user-friendly interface that provides tailored suggestions for optimizing energy use, such as adjusting heating, cooling, and lighting settings based on occupancy and individual habits.
- Ensure seamless connectivity and interoperability among various smart home devices to create a cohesive energy management ecosystem.

1.4 TECHNOLOGICAL BASE

This Project can be implemented by using various technologies like-

ThingSpeak

ThingSpeak™ is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams. Once you send data to ThingSpeak from your devices, you can create instant visualizations of live data without having to write any code. ThingSpeak™ is an IoT analytics platform service from MathWorks®, the makers of MATLAB® and Simulink®. ThingSpeak allows you to aggregate, visualize, and analyze live data streams in the cloud. ThingSpeak provides instant visualizations of data posted by your devices or equipment.

Advantages of ThingSpeak –

- **Data analysis**
  ThingSpeak allows you to analyze data using MATLAB. You can also perform online analysis and process data as it comes in.

- **IoT system development**
  You can prototype and build IoT systems without setting up servers or developing web software.

- **Event-based alerts**
  You can create sophisticated event-based email alerts that trigger based on data coming in from your connected devices.

- **Cloud-to-cloud integrations**
  You can integrate ThingSpeak with other services like The Things Network, Senet, the Libelium Meshlium gateway, and Particle.io.

- **Apps for integration**
  ThingSpeak provides apps for integration with web services, other APIs, and social networks.

Limitations of ThingSpeak –

- **Message limits**
  Free users are limited to 10 million messages per year, while paid users are limited to 100 million messages per unit per year.
- **Update interval**
  Free users can update a channel every 15 seconds, while paid users can update every second.
- **Storage**
  If storage is exceeded, channels may no longer be able to receive data.
- **Number of channels**
  The number of channels allowed depends on the license type:
  Standard: 4 channels per unit
  Academic, Student, and Home: 250 channels per unit
- **Private channel sharing**
  The number of times a private channel can be shared depends on the license type:
  Standard: Limited to 3 shares per unit
  Academic, Student, and Home: Unlimited shares per unit
- **Long term archiving**
  Paid customers can archive data long term by emailing thingspeak-sales@mathworks.com.

IOT (Internet Of Thing)

The Internet of Things (IoT) is a network of connected devices that can communicate with each other and the cloud. The goal of IoT is to create self-reporting devices that can communicate in real time.IoT devices are pieces of hardware, such as sensors, actuators, gadgets, appliances, or machines, that can transmit data over the internet. Sensors detect changes in the environment, such as temperature, humidity, light, motion, or pressure. Actuators can cause physical changes in the environment, such as opening or closing a valve or turning on a motor.

Some examples of IoT devices include:

- Smart washing machines
- Smart TVs
- Vacuum cleaners
- Smart toothbrush
- Smart lights
- Pet finders (tracking devices)
- Smart baby monitor

IoT can be categorized into four main types: Consumer IoT, Commercial IoT, Industrial IoT (IIoT), and Infrastructure IoT.

IoT can be used in a variety of ways, including:

- **Farming**

  IoT can be used to monitor soil conditions, optimize crop production, and manage livestock.

- **Wearables**

  IoT wearable devices can gather information about vital signs and other health metrics.

CHAPTER NO. 2

LITERATURE SURVEY

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE SURVEY

In order to carried out proposed approach we have gone through different literatures that are as follows :

1) **Paper Name: Smart Home Energy Management Using IoT**

   Publication Date: 2022

   Concept: The paper explores the use of IoT devices for monitoring and controlling home energy consumption. It incorporates machine learning to predict energy needs and optimize usage for efficiency, with an emphasis on reducing overall energy consumption and minimizing carbon footprints.

   Publisher: IEEE

   Publisher Persons: A. Khan, M. S. K. Choi

2) **Paper Name: Energy-Efficient Smart Homes: A Review of IoT and AI Applications**

   Publication Date: 2021

   Concept: This review paper discusses various IoT technologies combined with AI to enhance energy efficiency in smart homes. It analyzes different frameworks, devices, and algorithms, specifically targeting energy savings and carbon reduction.

   Publisher: Elsevier

   Publisher Persons: J. Lee, S. Kim

3) **Paper Name: IoT-Based Home Automation System for Energy Efficiency**

   Publication Date: 2023

   Concept: Focuses on a home automation system powered by IoT sensors that track and manage energy consumption in real-time. The paper integrates AI algorithms to provide personalized energy-saving recommendations based on usage patterns.

   Publisher: Springer

   Publisher Persons: R. Sharma, N. Singh

4) Paper Name: AI-Driven Energy Management for Smart Homes

Publication Date: 2024

Concept: This paper proposes a framework for intelligent energy management using AI. It leverages predictive models to anticipate energy demand and adjusts home devices accordingly, achieving optimal energy efficiency and reducing the carbon footprint.

Publisher: Wiley

Publisher Persons: P. Desai, M. Mehta

5) Paper Name: Sustainable Smart Home Automation for Energy Conservation

Publication Date: 2021

Concept: The research focuses on energy-saving mechanisms within smart homes, integrating renewable energy sources like solar panels with smart home systems powered by IoT and AI.

Publisher: Taylor & Francis

Publisher Persons: L. Xu, H. Liu

6) Paper Name: Reducing Carbon Footprint with Smart Home Automation Systems

Publication Date: 2022

Concept: Investigates how smart homes can reduce carbon footprints by using intelligent automation systems that manage heating, lighting, and electrical appliances based on the occupants' needs, powered by IoT devices and AI algorithms.

Publisher: Springer

Publisher Persons: R. Patel, A. Verma

7) Paper Name: IoT and AI for Green Energy Management in Smart Homes

Publication Date: 2023

Concept: This paper discusses the application of IoT and AI to integrate green energy technologies, such as solar power and energy storage systems, with smart homes to provide a sustainable solution for energy management.

Publisher: Elsevier

Publisher Persons: Y. Zhao, L. Chen

8) Paper Name: Smart Home Systems for Environmental Sustainability

Publication Date: 2021

Concept: Focuses on how smart home systems can contribute to environmental sustainability. It covers various IoT applications and AI-based systems to optimize energy usage and decrease home energy-related emissions.

Publisher: IEEE

Publisher Persons: A. Gupta, N. Suresh

9) Paper Name: IoT-Enabled Smart Homes for Carbon Reduction

Publication Date: 2022

Concept: Explores the potential of IoT devices in achieving a substantial reduction in household carbon emissions by creating an energy-efficient and environmentally friendly smart home system.

Publisher: Springer

Publisher Persons: H. Singh, S. Jadhav

10) Paper Name: Personalized Energy Management Systems in Smart Homes Using AI

Publication Date: 2024

Concept: The paper details the role of AI in personalizing energy management in homes, adapting the system based on the user's preferences and behaviors to optimize energy consumption.

Publisher: Wiley

Publisher Persons: K. Kaur, S. Nair

11) Paper Name: Machine Learning for Energy Optimization in Smart Homes

Publication Date: 2023

Concept: Focuses on using machine learning algorithms to optimize energy consumption in smart homes. It discusses the use of IoT devices for real-time energy monitoring and predictive optimization.

Publisher: IEEE

Publisher Persons: V. Gupta, R. Sharma

12) Paper Name: AI-Based Smart Home Systems for Sustainable Energy Management

Publication Date: 2022

Concept: The research paper examines AI-powered systems for managing energy in homes. It introduces intelligent decision-making processes for energy use, minimizing waste and enhancing sustainability.

Publisher: Elsevier

Publisher Persons: L. Zhang, P. Jha

2.2 FINDINGS

Table 1: Analysis of existing models

1) P. Kumar et al., 2021 (IoT-based Smart Energy Management for Smart Homes)	IoT-based smart energy management system using sensors and AI algorithms to optimize energy usage	Real-time monitoring, cost-efficient, energy-saving, adaptive learning.	Data privacy concerns, network latency, integration complexity.
2) R. Sharma et al., 2020 *(AI and IoT for Carbon Footprint Reduction in Smart Homes)*	Integration of AI for personalized energy management, combined with IoT devices to monitor consumption and reduce carbon emissions.	Personalized energy control, reduction in energy waste, sustainability focus.	High implementation cost, need for continuous system updates, dependency on internet connectivity.
3) S. Tan et al., 2019 *(IoT and AI for Energy Optimization in Smart Homes)*	Machine learning techniques (predictive analytics) to forecast energy demand, IoT for real-time data collection, and adaptive algorithms for consumption management.	Optimized energy usage, reduced operational costs, enhanced sustainability.	Scalability issues, complexity in real-time data processing, device compatibility.
4) M. Lee et al., 2022 *(AI-Driven Home Automation System for Carbon Footprint Reduction)*	Smart home system with AI integration for optimizing HVAC systems and lighting control.	Improved comfort, reduced carbon emissions, proactive energy savings.	Energy consumption spikes during transitions, user adaptation to new systems.

2.3 RELATED/EXISTING WORK

Nest Learning Thermostat (Google)

Work: Nest is an AI-driven smart thermostat that learns a user's temperature preferences and schedules to optimize energy usage. It connects to IoT devices within the home, like HVAC systems, and adjusts heating or cooling based on occupancy and external weather data. This personalized control helps reduce unnecessary energy consumption, ultimately lowering the carbon footprint.

EcoBee Smart Thermostat

Work: Like Nest, EcoBee uses IoT and AI algorithms to learn user behavior and optimize heating and cooling for efficiency. It integrates with other IoT devices like smart lights and appliances, offering an energy-saving ecosystem. The AI uses data from the home's occupants, weather forecasts, and energy consumption patterns to personalize settings, aiming for reduced energy bills and carbon emissions.

Tesla Powerwall

Work: The Tesla Powerwall is a battery storage system that uses AI to manage energy within homes. It stores solar energy generated during the day and intelligently distributes it when energy demand is high or during a power outage. The integration of IoT ensures that homes use renewable energy efficiently, thus minimizing the carbon footprint.

Philips Hue Smart Lighting System

Work: Philips Hue is an IoT-based lighting solution that allows users to control lighting remotely via a smartphone app. It uses AI to adjust lighting based on user activity and time of day, reducing energy consumption. Smart sensors detect motion, turning lights off in unoccupied rooms. This system helps reduce unnecessary energy usage, contributing to lower carbon emissions.

Smart Home Energy Management System (by Schneider Electric)

Work: Schneider Electric offers an integrated energy management system for homes that combines IoT with AI to optimize energy use across multiple devices. It monitors and controls appliances, heating, lighting, and renewable energy sources (like solar panels) to reduce waste. The AI-driven platform predicts energy consumption patterns and makes real-time adjustments, helping reduce the overall carbon footprint

2.4 REAL-TIME SURVEY

1. Purpose:

The software will collect real-time data on energy consumption, user behavior, and environmental factors (such as temperature, humidity, solar generation, and grid usage) from IoT-enabled devices in the home.It helps in understanding how the household uses energy and interacts with the home automation system.The goal is to optimize energy usage to reduce the carbon footprint, potentially adjusting energy consumption in real-time based on user preferences and environmental conditions.

2. Features:

- Data Collection: The software would gather information from IoT sensors, such as smart thermostats, lighting systems, appliances, and energy meters.
- User Feedback Integration: Surveys or questionnaires may allow users to input preferences for comfort, cost-saving, or eco-friendly options.
- Real-time Analytics: The software can process and analyze data instantly to recommend or make decisions for optimizing energy use.
- Predictive Insights: By using AI, the software can predict energy consumption patterns, identify potential savings, and suggest eco-friendly adjustments to the system.
- User Notifications: Real-time alerts for users regarding excessive energy consumption, carbon footprint estimates, or potential savings.
- Energy Optimization Algorithms: AI can be used to suggest the best energy usage patterns or automate appliances to work at optimal times.

3. IoT Integration:

- The software can interface with a variety of smart devices connected to the home network, including lighting, heating, cooling, and appliances.
- It could adjust settings in response to changes in environmental conditions, like adjusting HVAC usage based on room temperature or controlling lights based on occupancy.

4. Data Security & Privacy:

Real-time data collection should prioritize user privacy and security, ensuring that any sensitive data is encrypted and stored securely.

5. Carbon Footprint Reduction:

The system can offer insights into the household's overall carbon emissions based on its energy consumption. It could recommend or automatically implement changes to reduce energy consumption during peak hours or switch to renewable energy sources where possible.

CHAPTER NO. 3

METHODOLOGY / PROPOSED WORK

CHAPTER 3

METHODOLOGY / PROPOSED WORK

3.1 PROPOSED WORK

Integration of AI and IoT for smart home automation involves using Artificial intelligence (AI) to enhance the competencies of connected gadgets in a clever domestic environment. This integration permits gadgets to talk, examine records, and make decisions to automate diverse tasks[12], improve strength performance, enhance protection, and provide convenience to users. Here is an in-depth proposed device for integrating AI and IoT in smart home automation:

- Smart home gadgets: The machine consists of numerous IoT gadgets, including smart thermostats, lights, cameras, door locks, and sensors that accumulate facts and interact with the surroundings.
- IoT Gateway: A primary IoT gateway tool is used to attach and manage communique between the clever home gadgets and the AI device.
- AI Engine: An AI engine is the core factor of the gadget accountable for processing records, making choices, and controlling clever home devices based totally on predefined guidelines or device gaining knowledge of algorithms.
- Data Collection: Sensors and gadgets accumulate statistics, including temperature, humidity, motion, and mild levels, which are then dispatched to the AI engine for analysis.
- Data Processing: The AI engine approaches the collected facts through the usage of gadget learning algorithms to discover styles, traits, and anomalies to make knowledgeable choices.
- Decision Making: based on the processed data and predefined regulations, the AI engine makes selections, which include adjusting the thermostat, turning on/off lighting fixtures, or locking/unlocking doors to optimize comfort, energy performance, and protection.
- Automation and Control: The AI engine sends instructions to the IoT gateway, which then controls the smart home devices to carry out automatic moves.
- User Interface: A consumer interface, inclusive of a cell app or internet interface, permits users to display and manage their smart domestic devices manually, override computerized movements, or set alternatives and schedules.
- Machine learning and Adaptation: The gadget continuously learns from personal interactions and feedback to improve its decision-making technique and adapt to converting personal possibilities and environmental situations.
- Security and privacy: robust encryption and authentication mechanisms are applied to ensure the security and privacy of information transmitted among gadgets and the AI engine.

- Electricity Efficiency: The gadget optimizes electricity usage using intelligently controlling devices based totally on occupancy, personal preferences, and outside elements consisting of weather situations.
- Scalability and Interoperability: The gadget is designed to be scalable to aid a large variety of devices and interoperable with different brands and styles of clever domestic gadgets.

1. Model Designing:

The **Model Designing** module focuses on developing an advanced framework that leverages generative AI algorithms. These algorithms analyze real-time data from IoT-enabled devices, such as smart thermostats, lighting systems, and energy meters, to learn user behavior and preferences. The model is trained on diverse datasets to predict and recommend optimal energy consumption patterns while ensuring user comfort. The integration of cloud-based platforms enhances scalability and real-time data processing capabilities, ensuring the system adapts to dynamic environments and changing user habits.

- **Data Collection and Analysis**: Gathering real-time data from IoT-enabled sensors (e.g., temperature, motion, light, and energy consumption data).
- **AI Model Development**: Leveraging Generative AI to design models capable of learning user preferences and predicting energy-efficient behaviors.
- **Integration of Predictive Analytics**: Using machine learning techniques to anticipate energy requirements and optimize resource utilization dynamically.
- **Carbon Footprint Estimation Module**: Building algorithms to calculate and monitor the household's carbon footprint in real time.

1. Application:

The **Applications** module involves the implementation of the designed model into practical home automation solutions. This includes deploying IoT devices for monitoring and controlling household energy usage and integrating them with the generative AI system for personalized decision-making. For example, the system can adjust lighting intensity, optimize HVAC settings, or suggest appliance usage schedules based on energy-saving goals and real-time electricity pricing. Additionally, it incorporates user-friendly interfaces for manual overrides and feedback, ensuring flexibility and user engagement.

This module focuses on implementing the AI and IoT models in practical home automation scenarios, ensuring ease of use and impact. Key aspects include:

- **Smart Device Control**: Automating devices like lighting, HVAC systems, and appliances based on user preferences and energy efficiency goals.
- **Personalized Energy Management**: Providing real-time suggestions and adjustments to reduce energy consumption without compromising comfort.
- **User Dashboard**: Creating an intuitive interface where users can monitor energy usage, carbon footprint, and savings.
- **Feedback Loop**: Enabling users to provide feedback that refines the AI's recommendations and enhances personalization.

3.2 SYSTEM ARCHITECTURE

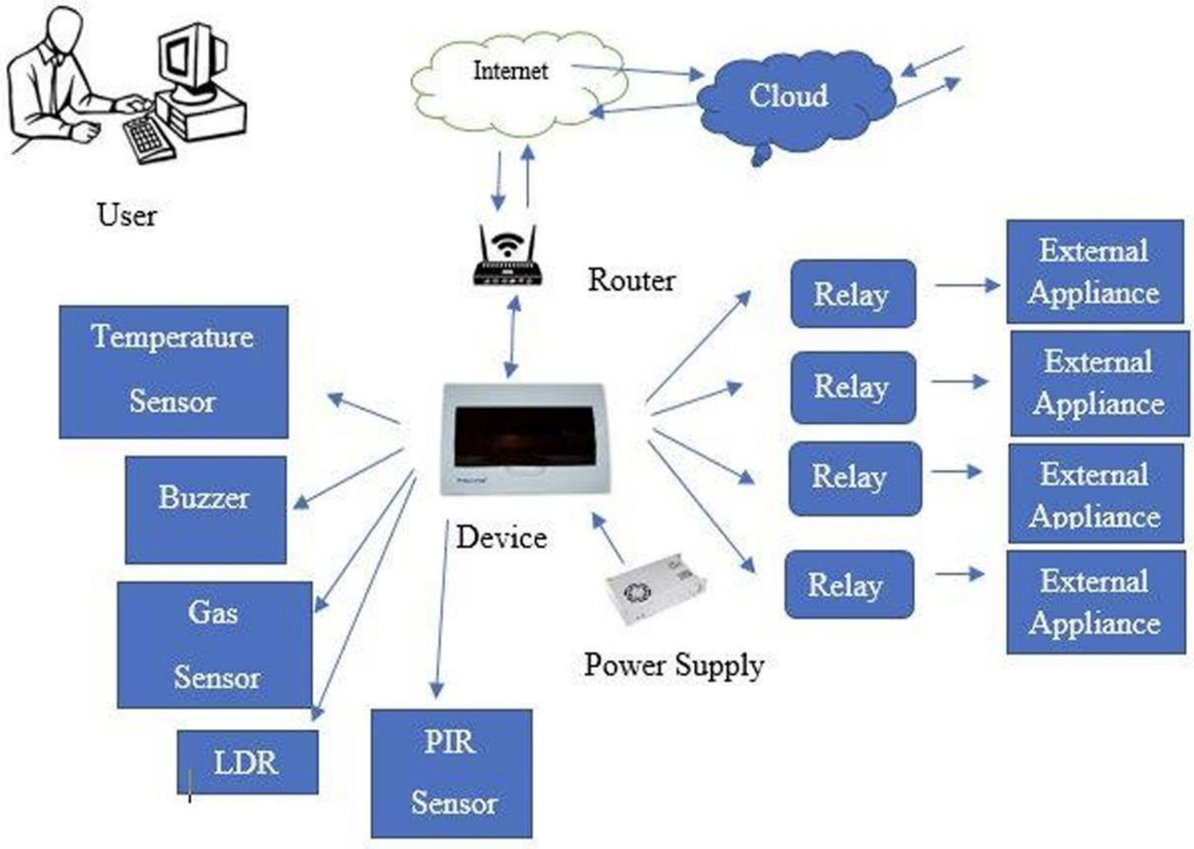


Fig 3.2 System Architecture

The diagram illustrates the methodology for an intelligent home automation system that leverages IoT and cloud computing for managing appliances based on environmental conditions. Here's an explanation of the components and their roles in the system:

1. **User Interface:**

   The user, represented by a computer or mobile interface, interacts with the system via the internet. This interface allows the user to monitor and control appliances in the home environment.

2. **Internet and Cloud Connectivity:**

   - **Router:** The system is connected to the internet through a router, which enables communication data to between the home automation system and the cloud.
   - **Cloud Platform:** A cloud server (e.g., ThingSpeak or AWS IoT) stores the sensor data, processes it, and helps automate appliance control. The cloud also enables remote access and data analytics.

3. Sensors:

- **Temperature Sensor:** Monitors the room's temperature, sending data to the device (ESP8266 or microcontroller).
- **LDR (Light Dependent Resistor):** Measures the ambient light levels, helping to control lighting automatically based on external light conditions.
- **PIR (Passive Infrared) Sensor:** Detects motion in a room to automate lights and appliances based on occupancy.
- **Buzzer:** Provides audio alerts for various scenarios, like detecting gas leaks or intrusions.

4. Device (Controller):

This central unit, typically an ESP8266 or similar microcontroller, gathers data from sensors and communicates with the cloud platform. It makes decisions about appliance control based on sensor input and cloud-based AI algorithms.

5. Power Supply:

The system includes a power supply unit that ensures continuous operation of the device and connected sensors.

6. Relays:

Relays are used to control external appliances like fans, lights, air conditioners, and other devices. These relays receive signals from the controller to switch appliances on or off.

7. External Appliances:

These are household devices that are controlled by the system. The control is automated based on the real-time data gathered from the environment and user preferences.

8. Data Flow:

- Sensors constantly monitor the environment and send the **Device (Controller)**.
- The **Controller** processes the sensor data, sends it to the **Cloud**, and follows instructions (or automates actions) based on pre-set logic and conditions (e.g., if the room is dark, turn on the light).
- The cloud platform provides additional functionality like remote access, data analysis, and long-term storage of sensor readings.

3.3 ALGORITHM/PSEUDO CODE/PROCEDURE

Algorithm

1. **Initialize System**
    - Connect IoT sensors and devices (temperature, motion, lighting, energy meters).
    - Initialize Generative AI and machine learning modules.
2. **Data Collection**
    - Continuously collect real-time data from IoT sensors: Temperature, Light Intensity, Energy Consumption, User Presence.
    - Store the data in a cloud-based system for processing.
3. **User Behavior Analysis**
    - Analyze historical data to understand user preferences and patterns.
    - Identify peak usage times, appliance preferences, and comfort levels.
4. **Predictive Energy Management**

    Use Generative AI to predict energy needs based on:
    - Current sensor data.
    - User behavior patterns.
    - Weather forecasts and time of day.
5. **Optimization Process**

    Calculate real-time energy requirements:
    - If user_present = TRUE: Adjust settings for optimal comfort and efficiency.
    - If user_present = FALSE: Switch devices to low-power or off mode.

    Generate alternative energy-saving scenarios using AI: Suggest reducing light brightness or using energy-efficient modes.
6. **Carbon Footprint Estimation**
    - Use energy consumption data to calculate carbon footprint using pre-defined conversion factors.
    - Log and display the estimated carbon emissions on the user dashboard.
7. **Feedback Loop**
    - Display energy usage and recommendations on the user interface.
    - Collect user feedback to refine AI-generated suggestions.
8. **Continuous Learning**
    - Update AI model using new sensor data and user feedback.
    - Optimize energy-saving recommendations and personalized settings over time.
9. **Output and Control**
    - Actuate IoT devices based on AI-driven decisions.
    - Provide real-time notifications for energy savings and carbon footprint reduction.

3.4 FLOW CHART

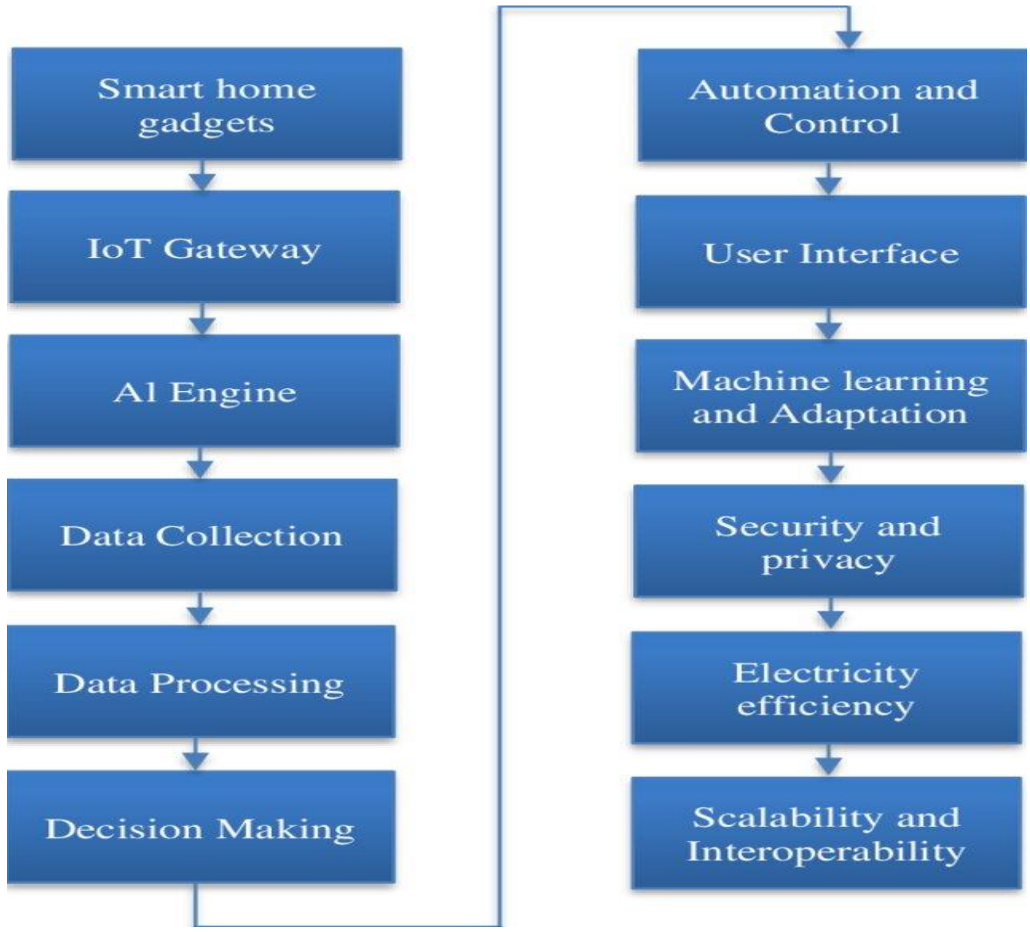


Fig. 3.4 Flow Chart / Diagram for AI and IoT in smart home automation

The integration of AI and IoT for smart home automation offers a complicated and shrewd way to control and manipulate various components of a smart home, supplying customers with comfort, consolation, and the best energy utilization.

CHAPTER NO. 4

TOOLS/PLATFORM

CHAPTER 4

Tools/Platform

4.1 SOFTWARE REQUIREMENT

1. **OS** – Windows 10
2. **Modelling and Implementation tool** – ThingSpeak
3. **IDE** – Ardiuno IDE
4. **Language** – C++
5. **Designing tool** – Blynk App

1. OPERATING SYSTEM –

Any Operating System which is having architecture of 32bit or higher is supported. We have used Windows 10 64bit with NVIDIA gpu**.**

2. ThingSpeak –

ThingSpeak is an IoT analytics platform designed to aggregate, visualize, and analyze live data streams in the cloud. It is particularly popular for its ease of use, making it an excellent choice for hobbyists, researchers, and developers looking to prototype IoT systems quickly without the need for extensive infrastructure.

Key Features:

<u>Real-Time Data Collection:</u>

ThingSpeak allows users to collect data from various sensors and devices connected to the internet in real-time. This means you can continuously monitor and gather data from multiple sources.

<u>Visualization:</u>

The platform provides built-in tools for creating visual representations of your data. This includes graphs, charts, and other widgets that make it easy to analyze trends and patterns visually.

MATLAB Integration:

One of ThingSpeak's standout features is its integration with MATLAB, a powerful tool for numerical computation and data visualization. This enables advanced data analysis and processing capabilities directly within ThingSpeak.

Event Scheduling:

ThingSpeak can automate actions based on specific events or time schedules. For instance, you can set triggers to send alerts, control devices, or execute MATLAB code when certain conditions are met.

API Support:

The platform offers RESTful and MQTT APIs, allowing easy integration with other services and enabling communication between IoT devices and ThingSpeak. This flexibility is vital for building complex IoT systems.

Device Compatibility:

ThingSpeak is compatible with a wide range of devices, including Arduino, Raspberry Pi, and ESP8266. This broad compatibility makes it easy to incorporate ThingSpeak into various IoT projects.

Advantages:

Ease of Use:

ThingSpeak's user-friendly interface simplifies the process of setting up and managing IoT data streams, making it accessible even to those with minimal technical expertise.

No Server Setup:

ThingSpeak is a hosted platform, so there is no need to set up or maintain your own servers. This reduces the overhead and complexity associated with managing an IoT infrastructure.

Community Support:

There is a robust community of users and developers who share tutorials, projects, and support. This community aspect helps newcomers get started and solve problems more quickly.

Versatility:

ThingSpeak supports a wide range of IoT applications, from environmental monitoring to smart farming and home automation. This versatility makes it a valuable tool for many different projects.

Cost-Effective:

The platform offers a free tier, which is sufficient for small-scale projects and prototypes. For larger projects, there are affordable paid plans that offer additional features and higher data limits.

Limitations:

Data Limits:

The free tier of ThingSpeak has limits on data storage and usage, which may be restrictive for larger projects or those requiring high-frequency data collection.

Complexity for Large-Scale Projects:

While excellent for small to medium-sized projects, ThingSpeak might not be the best choice for large-scale, production-grade IoT systems that require more robust infrastructure and scalability.

Dependency on MATLAB:

Advanced data analysis and processing are heavily dependent on MATLAB, which may involve additional costs and learning curves for users who are not familiar with it.

Limited Customization:

Compared to custom-built IoT solutions, ThingSpeak offers limited customization options. This can be a drawback for projects that need highly specific functionalities or integrations.

3. Arduino IDE –

The **Arduino Integrated Development Environment (IDE)** is a user-friendly platform designed for programming and uploading code to Arduino-compatible microcontrollers. Its intuitive interface caters to both beginners and experienced developers, making it easy to write, edit, and manage code. The code editor includes features like syntax highlighting, auto-completion, and error detection, which streamline the coding process and minimize errors.

One of the key features of the Arduino IDE is its extensive library support. The built-in library manager allows users to easily install, update, and manage libraries. These libraries provide pre-written code for a wide range of functions, such as handling sensor data, controlling actuators, and managing communication protocols. This reduces the complexity of coding, enabling users to focus more on their projects rather than on writing basic code from scratch.

The Arduino IDE also includes a serial monitor, which is crucial for debugging and monitoring the behavior of connected Arduino boards. The serial monitor allows developers to send and receive messages to and from the microcontroller, providing real-time insights into the program's performance and behavior. This feature is particularly useful for troubleshooting and refining code

The platform supports a wide range of Arduino boards and clones, making it highly versatile and adaptable to various projects. Users can easily select their board and port from the tools menu, ensuring compatibility and ease of use across different hardware platforms. This flexibility allows developers to experiment with different types of Arduino boards and components, broadening the scope of potential projects. Despite its many advantages, the Arduino IDE does have some limitations. As a Java-based application, it can sometimes be slow, especially on older or less powerful computers. Additionally, while it is perfect for beginners and intermediate users, the IDE lacks some advanced features found in more sophisticated Integrated Development Environments (IDEs) like Visual Studio Code or Eclipse. These limitations aside, the Arduino IDE remains an invaluable tool for prototyping, education, and hobbyist projects due to its simplicity, extensive library support, and robust community.

4. C++ -

C++ is a general-purpose programming language created by Bjarne Stroustrup as an extension of the C programming language. It is known for its versatility, allowing for both high-level and low-level programming. C++ is designed to provide a balance between performance and abstraction, making it suitable for a wide range of applications from system software to game development.

One of the key features of C++ is its support for object-oriented programming (OOP). This paradigm organizes software design around data, or objects, rather than functions and logic. Key concepts of OOP in C++ include classes, objects, inheritance, polymorphism, encapsulation, and abstraction. These features help in creating modular and reusable code, which can be easier to maintain and extend.

In addition to OOP, C++ also supports procedural programming, giving developers the flexibility to use the paradigm that best suits their needs. This dual paradigm capability allows for fine-grained control over system resources and memory management, which is crucial for performance-critical applications. The Standard Template Library (STL) in C++ provides a collection of pre-built classes and functions for common data structures and algorithms, promoting code reuse and efficiency.

Memory management in C++ is both a powerful and complex aspect of the language. Unlike languages with automatic garbage collection, C++ requires developers to manually manage memory allocation and deallocation. This can lead to highly optimized code but also increases the risk of errors such as memory leaks and pointer mismanagement. To assist with this, C++11 introduced smart pointers, which help manage dynamic memory more safely and efficiently.

C++ has a rich set of libraries and tools, making it highly versatile for various applications. It is widely used in developing operating systems, game engines, real-time simulation, embedded systems, and high-performance applications. Its performance efficiency and flexibility have kept it relevant in the software industry for several decades, despite the emergence of many newer languages.

4. BLYNK APP –

Blynk is a popular app for designing and managing IoT-based home automation systems. It allows users to create custom mobile and web interfaces to control and monitor connected devices. Blynk supports various hardware platforms like Arduino, Raspberry Pi, and ESP8266, making it versatile for different IoT projects. The app offers a drag-and-drop interface for building control panels and dashboards, simplifying the process for users without extensive programming skills. Blynk also integrates with AI and machine learning tools, enabling smart automation and intelligent decision-making in home automation systems.

Key Features

1. **No-Code Development**: Blynk allows users to create feature-rich IoT applications without writing any code. This is achieved through a drag-and-drop app constructor3.
2. **Real-Time Data Visualization**: Users can visualize and plot data from various sensors in real-time. This is useful for monitoring environmental conditions, energy consumption, and more.
3. **Device Control**: Blynk enables remote control of connected devices, such as relays, motors, and other electrical appliances.
4. **Push Notifications and Alerts**: The app can send push notifications and emails based on specific events or conditions, ensuring timely updates.
5. **Multi-Device Management**: Users can manage multiple devices within a single app, making it easy to control and monitor various IoT components.
6. **Over-The-Air (OTA) Updates**: Blynk supports seamless OTA firmware updates, ensuring that devices are always running the latest software.
7. **Security**: The platform provides enterprise-grade security features, including encrypted communications and role-based access control.
8. **Customization**: Users can customize the user interface (UI) elements, including size, color, font, and animations, to match their brand.
9. **Automation**: Blynk offers various automation features, allowing users to set up complex event-driven actions.
10. **Device Provisioning**: The app includes a built-in WiFi manager for easy device provisioning and profiling

Hardware Requirements

Microcontroller: NodeMCU (ESP8266) or ESP322

Relay Module: 2-channel or 4-channel relay module (5V)

Sensors: DHT11 or DHT22 (temperature and humidity)2, LDR (light sensor), PIR (Motion Sensor), Power Supply: 5V power supply or battery (depending on your setup)

ESP8266 to DHT11: The DHT11 sensor is connected to one of the GPIO pins of the ESP8266 for temperature and humidity data collection.

ESP8266 to Light Sensor:A photoresistor or LDR sensor connects to the ESP8266 to monitor natural light intensity.

ESP8266 to PIR Sensor: The PIR sensor connects to the ESP8266, enabling it to detect motion and decide whether to switch lights on or off.

Breadboard and Jumper Wires: For making connections

Home Appliances: Lights, fans, or other devices you want to control

CHAPTER NO. 5

DESIGN & IMPLEMENTATION

CHAPTER 5

DESIGN & IMPLEMENTATION

5.1 SYSTEM DESIGN

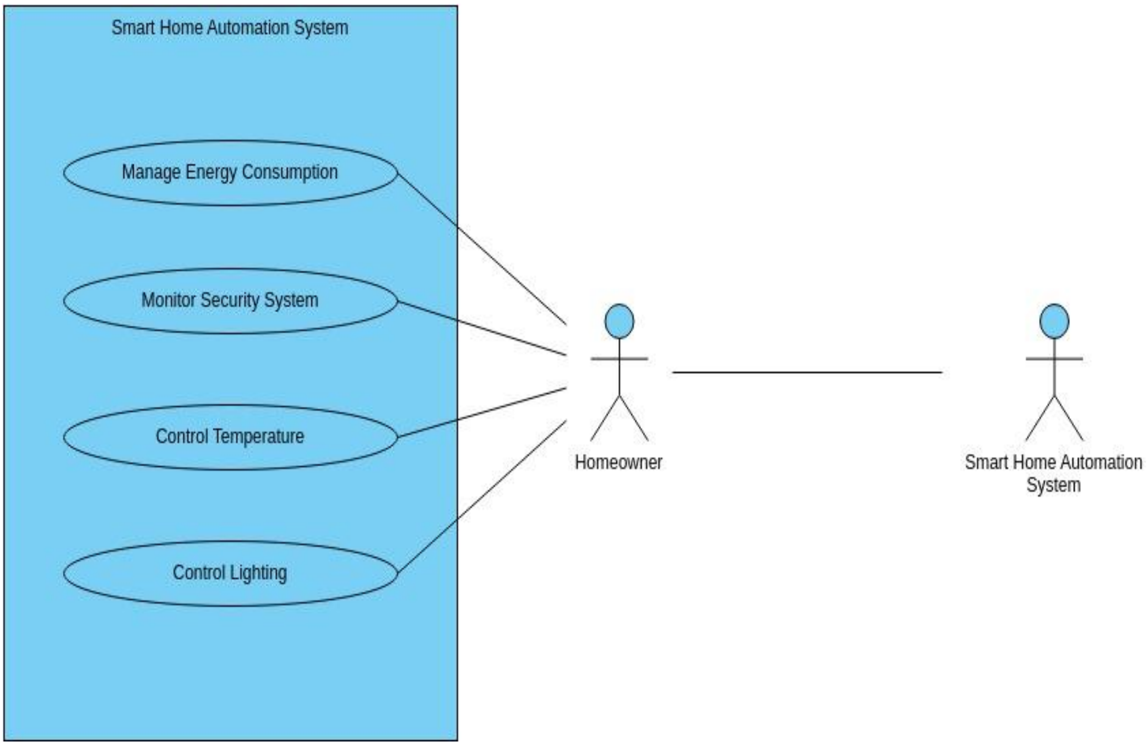


Fig. - 5.1.1: Use-Case Diagram

Actors –

In Use-Case diagram, the tasks performed by the users are listed below:

This flowchart illustrates the communication and data flow within a smart home or energy management system, highlighting the integration of various components and protocols for efficient monitoring and control. At the heart of the system is the middleware module, which acts as an intermediary, processing and managing data between different elements of the system.

The user control aspect allows homeowners to remotely manage their devices via MQTT (Message Queuing Telemetry Transport) publish commands. These commands are sent through the internet to the middleware module, which then relays them to the respective devices. This setup ensures that users can control their home appliances from anywhere, enhancing convenience and energy efficiency.

Monitoring is a critical function depicted in the flowchart, showcasing how device stat us and energy consumption details are collected and reported back to the system. Data flows include registration data, device control commands, status reports, and consumption details, all transmitted using MQTT and HTTP (Hypertext Transfer Protocol). The mobile app serves as an interface for users to interact with the system, providing a user-friendly platform to monitor and control their home environment. This flowchart effectively demonstrates the seamless integration of IoT technologies for real-time energy management and remote device control in modern smart home systems

5.1.2. DFD/ER/CLASS DIAGRAM:

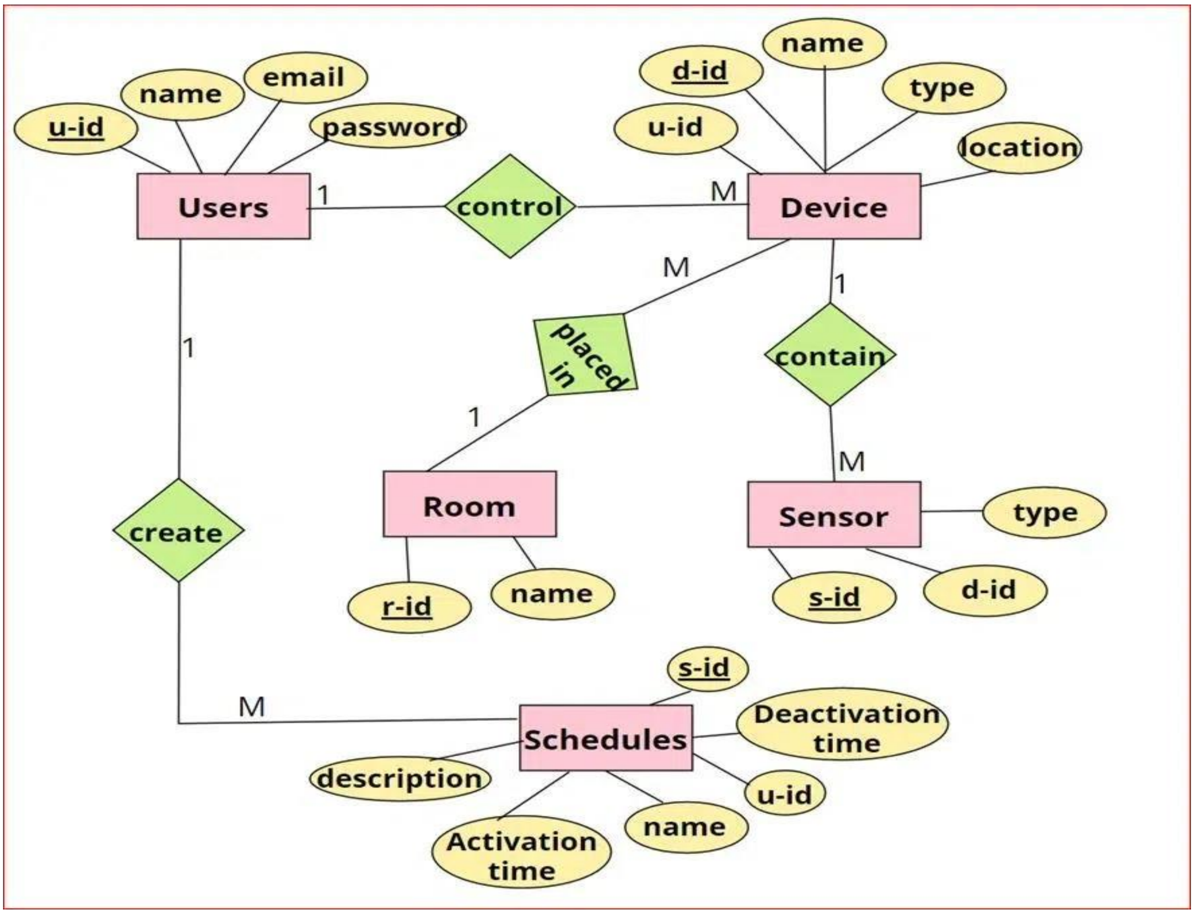


Fig. - 5.1.2: Class Diagram

This Entity-Relationship (ER) diagram visually represents the relationships between different entities in a smart home automation system. The main entities include "Users," "Devices," "Rooms," "Sensors," and "Schedules." Each entity is depicted as a rectangle, with attributes listed in ovals connected to them. For example, the "Users" entity has attributes like "u-id," "name," "email," and "password," while the "Devices" entity includes "d-id," "name," "type," "location," and "u-id."

The relationships between these entities are illustrated using diamonds, with connecting lines indicating how the entities interact. The "Users" entity has a one-to-many relationship with the "Devices" entity through the "control" relationship, showing that one user can control multiple devices. Similarly, the "Devices" entity is connected to the "Rooms" entity via a many-to-one "placed in" relationship, meaning multiple devices can be placed in one room. Additionally, the "Devices" entity has a many-to-one relationship with the "Sensors" entity through the "contain" relationship, indicating that a device can contain multiple sensors.

The "Schedules" entity plays a crucial role in this system, as it is linked to both the "Users" and "Sensors" entities through many-to-one relationships. This means that multiple schedules can be associated with a single user and sensor. The attributes of the "Schedules" entity, such as "description," "activation time," "deactivation time," "name," "s-id," and "u-id," help define the timing and conditions for activating or deactivating sensors within the smart home system. This diagram effectively organizes and clarifies the structure and interactions within the home automation system, which is essential for efficient database design and management.

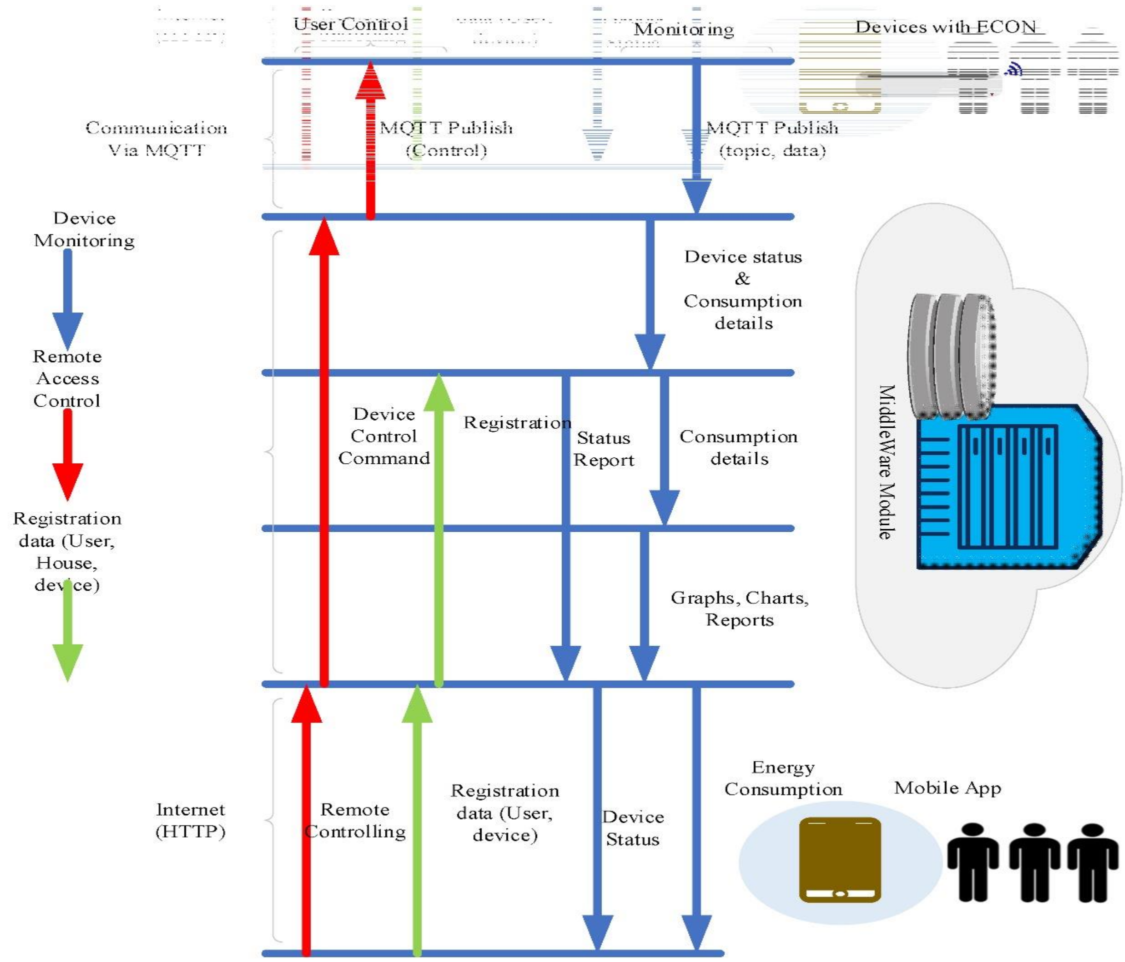


Fig 5.1.3 sequence diagram

The use case diagram for the Smart Home Automation System visually outlines the various functionalities and interactions within the system. The primary actor in the diagram is the homeowner, who interacts with the Smart Home Automation System to manage several key aspects of their home environment. Each use case represents a distinct function or service that the homeowner can control through the system.

Manage Energy Consumption is one of the core use cases, allowing the homeowner to optimize energy usage and potentially reduce costs by controlling appliances and monitoring energy consumption patterns. Monitor Security System is another crucial use case, enabling the homeowner to keep an eye on security cameras, motion sensors, and alarms to ensure the safety of their property. This functionality is vital for peace of mind and effective home security management.

Additionally, the system allows the homeowner to Control Temperature and Control Lighting. These use cases enable the homeowner to adjust heating, cooling, and lighting settings to enhance comfort and energy efficiency. For instance, the homeowner can set schedules for the thermostat or lighting to turn on or off at specific times, ensuring a comfortable living environment and saving energy when rooms are not in use. Overall, the diagram effectively illustrates how the Smart Home Automation System empowers homeowners to manage various aspects of their home environment seamlessly and efficiently.

5.2 Implementation of System

Implementing a smart home or energy management system involves several key steps, from initial setup to final deployment. Here’s a detailed guide to help you through the process:

1. System Design and Planning

- Identify Requirements: Determine the specific needs of your smart home system, including the types of devices and sensors you will use, the scope of automation, and the communication protocols (e.g., MQTT, HTTP).
- Create Diagrams: Design flowcharts and ER diagrams to visualize the system’s components, data flow, and relationships. This will help in planning and organizing the project.
- Choose Hardware: Select compatible hardware components such as microcontrollers (e.g., Arduino, ESP8266, or ESP32), sensors, actuators, and relay modules.

2. Setting Up the Hardware

- Assemble the Devices: Connect sensors and actuators to the microcontroller on a breadboard or custom PCB. Ensure proper wiring and connections for reliable operation.
- Power Supply: Ensure a stable power supply for all components. Use a suitable power adapter or battery, and verify voltage requirements.

3. Programming the Microcontroller

- Arduino IDE: Install the Arduino IDE on your computer and set up the necessary libraries for MQTT, sensor modules, and relay control.
- Write Code: Develop and upload code to the microcontroller for handling sensor readings, device control, and communication with the middleware and user interface.
- Test Functionality: Conduct preliminary tests to ensure the sensors and actuators respond correctly to the code.

4. User Interface Development

Mobile App: Develop or customize a mobile app to serve as the user interface. Use tools like Blynk or custom frameworks to create dashboards and control widgets.
Web Interface: Optionally, develop a web-based interface for remote control and monitoring of the smart home system.

5. Communication and Networking

- MQTT Protocol: Set up an MQTT broker for efficient communication between devices and the middleware. Ensure secure connections with proper authentication and encryption.
- Wi-Fi Configuration: Configure the microcontroller and devices to connect to the home Wi-Fi network. Ensure stable and reliable network connectivity.

5.3 Sample Code

5.3.1 Sample code for sensor configration

```
#include "DHT.h"
#include <ESP8266WiFi.h>
#include <ThingSpeak.h>

#define DPIN 4        // Pin to connect DHT sensor (GPIO number) D2
#define DTYPE DHT11   // Define DHT 11 or DHT22 sensor type
#define PIRPIN D5

// WiFi credentials
const char* ssid = "vivo T3 5G";          // Your WiFi SSID
const char* password = "1234567890";  // Your WiFi password

// ThingSpeak credentials
unsigned long myChannelNumber = 2689958;
const char* myWriteAPIKey = "ON0H58INN69KWRQM";

WiFiClient client; // WiFi client for ThingSpeak
DHT dht(DPIN, DTYPE);
int ldrPin = A0;         // LDR module connected to A0
int ledPin = D1;         // LED connected to pin D1 (GPIO5)
int threshold = 500;     // Light intensity threshold for LED

void setup() {
  Serial.begin(115200);
  dht.begin();


  pinMode(ledPin, OUTPUT);
  pinMode(PIRPIN, INPUT);

  // Connect to WiFi
  Serial.println("Connecting to WiFi...");
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }

  Serial.println("\nWiFi connected.");
  Serial.print("IP address: ");
  Serial.println(WiFi.localIP());

  ThingSpeak.begin(client); // Initialize ThingSpeak
}

void loop() {
  // Read sensor data
int lightLevel = analogRead(ldrPin);
```

```
  float tc = dht.readTemperature(false);  // Read temperature in C
  float hu = dht.readHumidity();          // Read Humidity

  // Print values to Serial
  Serial.println(lightLevel);
  Serial.print("Temp: ");
  Serial.print(tc);
  Serial.print(" C, Hum: ");


  Serial.print(hu);
  Serial.println("%");

  // Control LED based on light level
  if (lightLevel < threshold) {
    digitalWrite(ledPin, HIGH);
  } else {
    digitalWrite(ledPin, LOW);
  }

  // Check for motion
  int motionDetected = digitalRead(PIRPIN);
  if (motionDetected == HIGH) {
    Serial.println("Motion Detected!");
  } else {
    Serial.println("No Motion Detected");
  }

  // Update ThingSpeak
  ThingSpeak.setField(1, tc);      // Set field 1 to temperature
  ThingSpeak.setField(2, hu);      // Set field 2 to humidity
  ThingSpeak.setField(3, lightLevel); // Set field 3 to light level

  // Write to ThingSpeak
  int responseCode = ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);
  if (responseCode == 200) {
    Serial.println("Data updated successfully.");
  } else {


    Serial.print("Error updating data. HTTP response code: ");
    Serial.println(responseCode);
  }

  delay(10000);  // Wait 10 seconds before the next update
}
```

5.3.2 Sample code for Automation

```
#include <Adafruit_Sensor.h>
#include <DHT.h>

// Pin Definitions
#define PIR_PIN D5          // PIR sensor pin
#define DHT_PIN D6          // DHT11 sensor pin
#define DHT_TYPE DHT11      // DHT11 sensor type
#define LIGHT_SENSOR_PIN A0  // LDR connected to analog pin
#define RELAY1_PIN D1       // Relay 1 control pin
#define RELAY2_PIN D2       // Relay 2 control pin
#define RELAY3_PIN D3       // Relay 3 control pin
#define RELAY4_PIN D4       // Relay 4 control pin

// Initialize DHT sensor
DHT dht(DHT_PIN, DHT_TYPE);

// Variables
int pirState = LOW;  // PIR state
float temperature = 0.0;
float humidity = 0.0;
int lightLevel = 0;

void setup() {
  // Initialize serial communication
  Serial.begin(115200);
  Serial.println("Smart Home Control System");

  // Initialize sensors and relay pins
  dht.begin();
  pinMode(PIR_PIN, INPUT);
  pinMode(RELAY1_PIN, OUTPUT);
  pinMode(RELAY2_PIN, OUTPUT);
  pinMode(RELAY3_PIN, OUTPUT);


  pinMode(RELAY4_PIN, OUTPUT);

  // Turn off all relays initially
  digitalWrite(RELAY1_PIN, LOW);
  digitalWrite(RELAY2_PIN, LOW);
  digitalWrite(RELAY3_PIN, LOW);
  digitalWrite(RELAY4_PIN, LOW);
}

void loop() {
  // Read PIR sensor
  int motionDetected = digitalRead(PIR_PIN);

  // Read DHT sensor
  humidity = dht.readHumidity();
```

```
  temperature = dht.readTemperature();
  // Read Light Sensor
  lightLevel = analogRead(LIGHT_SENSOR_PIN);

  // Control appliances based on PIR sensor
  if (motionDetected == HIGH && pirState == LOW) {
    digitalWrite(RELAY1_PIN, HIGH); // Turn on appliance (e.g., light)
    Serial.println("Motion detected: Turning on light");
    pirState = HIGH;
  } else if (motionDetected == LOW && pirState == HIGH) {
    digitalWrite(RELAY1_PIN, LOW); // Turn off appliance
    Serial.println("No motion: Turning off light");
    pirState = LOW;
  }

  // Control appliance based on DHT11 temperature
  if (!isnan(temperature)) {
    if (temperature > 30.0) {
      digitalWrite(RELAY2_PIN, HIGH); // Turn on fan


      Serial.println("High temperature: Turning on fan");
    } else {
      digitalWrite(RELAY2_PIN, LOW); // Turn off fan
      Serial.println("Temperature normal: Fan off");
    }
  }

  // Control appliance based on DHT11 humidity
  if (!isnan(humidity)) {
    if (humidity < 40.0) {
      digitalWrite(RELAY3_PIN, HIGH); // Turn on humidifier
      Serial.println("Low humidity: Turning on humidifier");
    } else {
      digitalWrite(RELAY3_PIN, LOW); // Turn off humidifier
      Serial.println("Humidity normal: Humidifier off");
    }
  }

  // Control appliance based on light sensor
  if (lightLevel < 500) {
    digitalWrite(RELAY4_PIN, HIGH); // Turn on light
    Serial.println("Low light: Turning on light");
  } else {
    digitalWrite(RELAY4_PIN, LOW); // Turn off light
    Serial.println("Sufficient light: Light off");
  }

  // Small delay to stabilize sensor readings
  delay(2000);
}
```

CHAPTER NO. 6

RESULTS & DISCUSSION

CHAPTER 6

RESULTS & DISCUSSION

6.1 RESULT

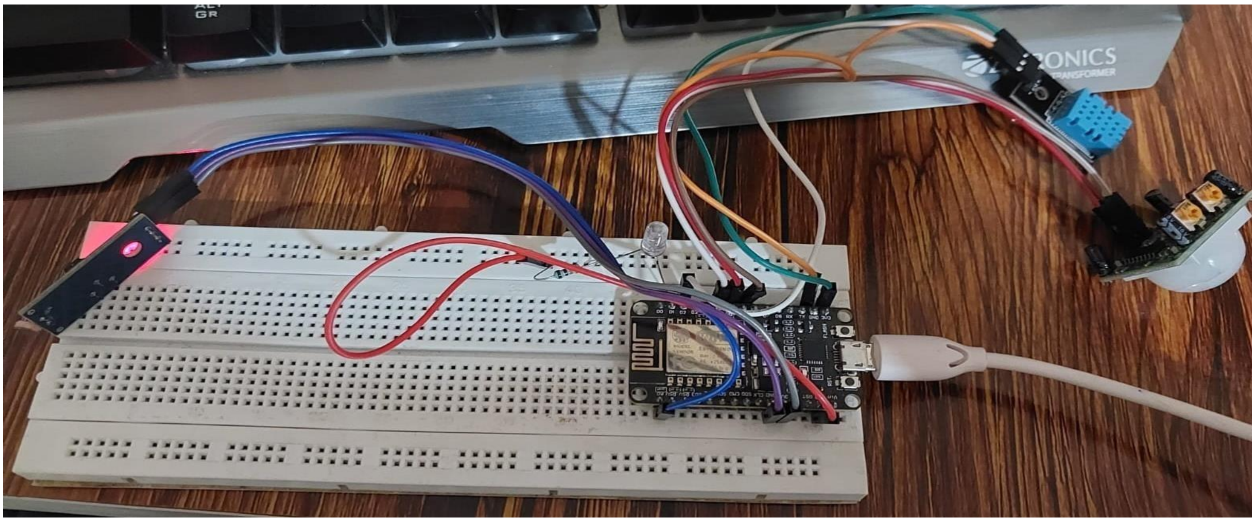


Fig 6.1.1 : Sensor configuration

We connect components on bread board with the help of Jumper wires .

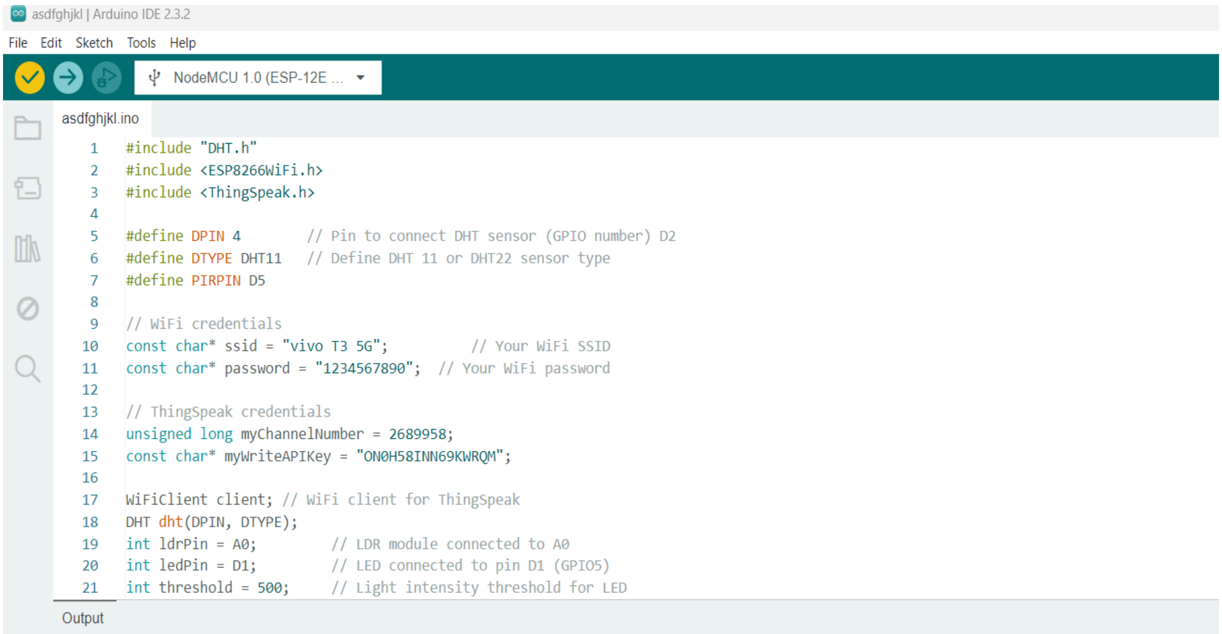


Fig 6.1.2 : Ardiuno IDE

Ardiuno IDE helps use upload the in nodemcu and we will easy read all the data form the sensors.

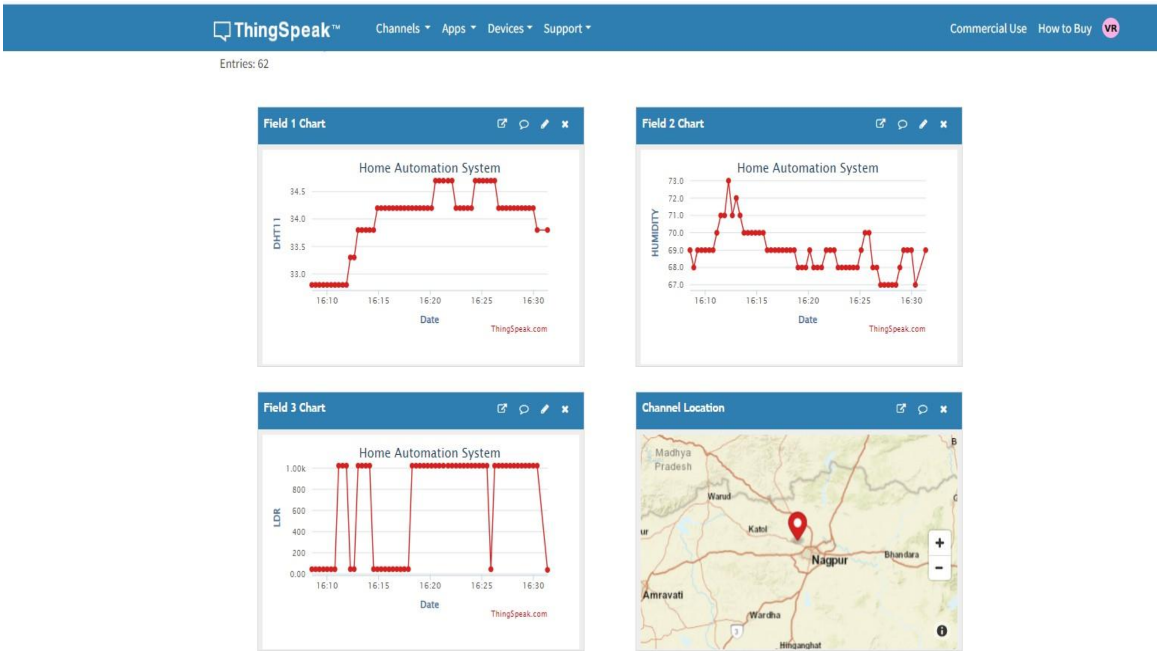


Fig 6.1.3 : ThingSpeak

Using thingspeak we visualize the and verify the data.

Fig 6.1.3 : Automation Diagram

Last we do automation on home appliances .

CHAPTER NO. 7

ADVANTAGES AND APPLICATIONS

CHAPTER 7

ADVANTAGES AND APPLICATIONS

7.1 ADVANTAGES

- Energy Efficiency: The system optimizes energy consumption by automatically controlling appliances based on real-time data from environmental sensors. This helps reduce unnecessary energy use, leading to lower utility bills and decreased carbon emissions.
- Improved Safety: The integration of sensors such as gas and motion detectors enhances home safety. The system can trigger alerts or automatically turn on ventilation in case of gas detection, and use motion sensors to light up spaces when someone enters.
- Data-Driven Insights: The cloud platform collects and analyzes data over time, providing users with insights into their energy consumption patterns and appliance usage. This information helps users make informed decisions about energy management and sustainability.
- Convenience and Automation: The system automates routine tasks (like turning off lights when a room is unoccupied) and enables remote access and control through smartphones or computers. This level of automation simplifies daily routines and enhances user convenience.

7.2 APPLICATIONS

- **Smart Energy Monitoring and Optimization**
  Real-time monitoring of energy consumption for appliances. Dynamic adjustments based on user preferences and schedules (e.g., turning off unused devices automatically). AI-driven suggestions for energy-efficient usage patterns.
- **Personalized Energy Recommendations**
  Using Generative AI to analyze historical energy consumption and suggest personalized strategies. Seasonal and weather-based recommendations (e.g., adjusting heating or cooling systems).
- **Intelligent Climate Control**
  Automated regulation of HVAC systems using IoT sensors for temperature, humidity, and occupancy. AI-generated patterns to minimize energy wastage while ensuring comfort.
- **Renewable Energy Management**
  Integration of solar panels, wind turbines, or other renewable energy sources.AI predicts energy production and manages storage or grid feedback efficiently.
- **Appliance Management**
  Smart scheduling for energy-intensive appliances like washing machines or dishwashers during off-peak hours.Detection and notification of malfunctioning or energy-hogging devices.

CHAPTER NO. 8

CONCLUSION & FUTURE SCOPE

CHAPTER 8

CONCLUSION & FUTURE SCOPE

8.1 CONCLUSION

The project on the "Intelligent Home Automation System Using Generative AI and IoT for Personalized Energy Management to Reduce Carbon Footprint" presents a transformative approach to modern energy consumption in households. By integrating advanced technologies, such as Generative AI and IoT, the system empowers users to optimize their energy usage in real time, leading to significant reductions in energy waste and carbon emissions. Through comprehensive research and development, the project aims to create a user-friendly platform that not only monitors and manages energy consumption but also educates and engages homeowners in sustainable practices. The personalized recommendations generated by the AI algorithms encourage proactive energy management, making it easier for individuals to adopt eco- friendly habits. Ultimately, this intelligent system contributes to a broader goal of environmental sustainability, aligning with global efforts to combat climate change. By demonstrating the effectiveness of smart home technologies in enhancing energy efficiency, the project paves the way for a more sustainable future, where households play an active role in reducing their carbon footprints while enjoying the conveniences of modern living.

8.2 FUTURE SCOPE

- **Enhanced Machine Learning Algorithms**:As machine learning techniques evolve, integrating more sophisticated algorithms can improve the accuracy of energy predictions and recommendations. Continuous learning models that adapt based on user feedback and changing behaviors will enhance system responsiveness.

- **Integration with Renewable Energy Sources**:Future systems could seamlessly integrate with solar panels, wind turbines, and other renewable energy sources. This would enable homeowners to optimize the use of clean energy, manage energy storage solutions, and reduce reliance on grid power, further decreasing carbon footprints.

- **Smart Grid Connectivity**:Connecting home automation systems to smart grids can facilitate real-time energy trading and load balancing. Homes could participate in demand-response programs, receiving incentives for reducing energy consumption during peak periods.

REFERENCES

Papers:

[1] A. Z. Alkar and U. Buhur, "An Internet based wireless home automation system for multifunctional devices," Consumer Electronics, IEEE Transactions on, vol. 51, pp. 1169- 1174, 2005.

[2] Ejaz Ahmed, Ibrar Yaqoob, Abdullah Gani, Muhammad Imran, and Mohsen Guizani,IEEE Wireless Communications “Internet-of-Things-Based Smart Environments: State of the Art, Taxonomy, and Open Research Challenges”, 1536 1284,October 2016

[3] C. Chiu-Chiao, H. Ching Yuan, W. Shiau-Chin, and L. Cheng-Min, "Bluetooth-Based Android Interactive Applications for Smart Living," in Innovations in Bio-inspired Computing and Applications (IBICA), 2011 Second International Conference on, 2011, pp. 309-312.

[4] G.Kortuem, F.Kawsar, D.Fitton, and V.Sundramoorthy,"Smart objects as building blocks for the internet of things," Internet Computing, IEEE, vol. 14, pp. 44-51, 2010.

[5] Luca Mainetti, Vincenzo Mighali, Luigi Patrono ”An IoT-based Usercentric Ecosystem for Heterogeneous Smart Home Environments”, IEEE ICC 2015 SAC - Internet of Things,pp. 704-709.

[6] R. Piyare and M. Tazil, "Bluetooth Based Home Automation System Using Cell Phone," in Consumer Electronics (ISCE), 2011 IEEE 15th International Symposium on, 2011, pp. 192-195.

Websites:

1. https://ieeexplore.ieee.org/Xplore/home.jsp
2. https://link.springer.com/
3. https://www.researchgate.net/
4. https://www.iotforall.com/
5. https://www.greenbuildingadvisor.com/

Books/Articles:

1. Smart Homes and Their Users" by Jennifer S. Preece and David P. G. B. Reddy

2. Artificial Intelligence for Smart Cities" by Pradeep Kumar and Shailesh Kumar

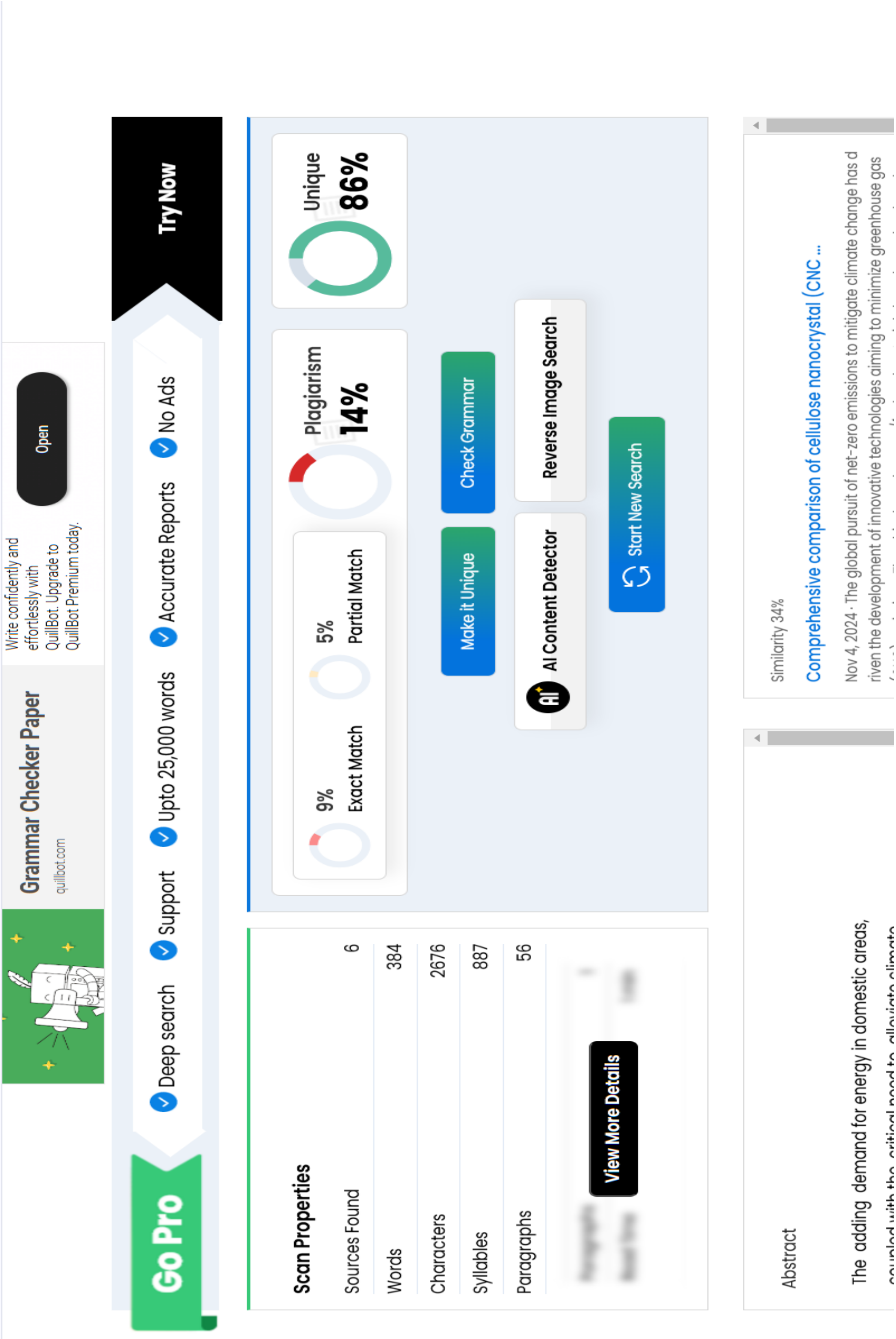
3. The Smart Home Manual: How to Create the Ultimate Connected Home" by
E. Brian E. Smith

4. Energy Management Systems: Operation and Control" by D. H. Wang and W.H. K. Lam

APPENDIX I

PLAGIARISM REPORT

PLAGIARISM REPORT



APPENDIX II

PUBLISHED PAPER

"Intelligent Home Automation System Using Gen Ai And Iot For Personalized Energy Management To Reduce Carbon Footprint"

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Abstract

The increasing demand for energy in residential areas, coupled with the urgent need to mitigate climate change, has driven the development of innovative solutions that promote energy efficiency and reduce carbon emissions. This paper introduces an advanced home automation system that combines the power of Generative Artificial Intelligence (Gen AI) and the Internet of Things (IoT) to offer a personalized energy management platform aimed at minimizing energy consumption and reducing a household's carbon footprint. The system utilizes the ESP8266 microcontroller and is equipped with a variety of sensors, including temperature and humidity sensors (DHT11), light sensors, and motion sensors, to monitor the environmental conditions of the home in real time.

By leveraging the data collected from these sensors, a Gen AI model learns the behavioral patterns and preferences of household occupants, enabling predictive and automated control of household appliances. The AI-driven automation focuses on optimizing the operation of lighting systems, particularly by turning lights on or off based on the presence of individuals and the ambient light conditions. This results in significant energy savings by ensuring that lights are only in use when necessary, and natural light is fully utilized.

In addition to energy-saving measures, the system provides users with real-time data monitoring and control through integration with the ThingSpeak cloud platform. ThingSpeak allows for seamless communication between the IoT devices and a user-friendly interface where users can track energy usage, receive insights on their energy consumption patterns, and manually override automated settings when needed. The system is designed to adapt to each user's unique lifestyle, improving overall energy efficiency without compromising comfort.

This paper not only highlights the technical aspects of the hardware and software integration but also emphasizes the environmental impact of the system.

Through predictive energy management, the proposed solution demonstrates a reduction in energy consumption and a corresponding decrease in the carbon footprint of the household. The research contributes to the growing field of smart home technologies that aim to enhance sustainability by intelligently managing energy resources. Moreover, the system can be expanded to control other household appliances, further amplifying its potential for energy conservation. As global efforts to combat climate change intensify, this project showcases the value of integrating AI and IoT technologies to support the transition toward a more sustainable and eco-friendly future.

Scope

The scope of this project encompasses the development and implementation of an intelligent home automation system that leverages both Generative AI (Gen AI) and Internet of Things (IoT) technologies to create a personalized energy management platform. The system is designed to monitor and control household appliances, with a primary focus on lighting systems, aiming to optimize energy usage and reduce the carbon footprint of residential spaces. This solution addresses several key aspects, including data collection from sensors, real-time data analysis, AI-driven automation, user interaction through cloud platforms, and energy efficiency.

1. IoT-Based Environmental Data Monitoring

The foundation of the system lies in its IoT network, which uses the ESP8266 microcontroller to interface with various environmental sensors such as the DHT11 (for temperature and humidity), light sensors (for ambient light levels), and motion detectors (for presence detection). These sensors continuously gather real-time data from the home environment.
The scope includes designing a robust network where these sensors reliably transmit data to the microcontroller for further processing, ensuring accurate and timely monitoring of the home's environmental conditions.

2. Generative AI for Behavioral Prediction and Automation

One of the core elements of this system is the integration of Generative AI to analyze the data collected from the IoT sensors. The AI model is designed to learn the behavioral patterns, preferences, and habits of household occupants over time. For example, it recognizes the times when lights are typically turned on or off based on occupancy or external lighting conditions. This predictive learning capability allows the system to automatically adjust the operation of appliances, primarily lighting, to minimize energy consumption without compromising user comfort. The scope covers the design, training, and implementation of the AI model, ensuring it adapts to the evolving needs of the household.

3. Automated Appliance Control

The system's automation feature is another major component. Based on the insights generated by the AI model, the system automatically controls household appliances such as lights. The automation includes turning lights on when motion is detected and off when no motion is detected, as well as adjusting light intensity based on the amount of natural light available. This automatic control ensures energy savings by reducing unnecessary use of appliances. The scope includes developing algorithms that balance energy optimization with maintaining a comfortable living environment.

4. Cloud Integration and User Interaction through ThingSpeak

To provide users with the ability to monitor and control the system remotely, the project integrates ThingSpeak, a cloud-based platform. Data collected from the sensors is transmitted to ThingSpeak in real time, where users can visualize and analyze the system's performance, track energy usage trends, and receive insights on how their energy consumption affects their overall carbon footprint. The platform also allows for manual control of the automated settings, giving users the flexibility to override the system's automated decisions when necessary. The scope includes the design of an intuitive user interface and the establishment of reliable data communication between the IoT network and ThingSpeak.

5. Energy Consumption Optimization

The primary objective of this system is to optimize energy usage in the household. The scope covers the design and implementation of energy management strategies that minimize energy consumption by intelligently adjusting appliance operation based on environmental conditions and learned user behavior. By reducing the time lights and other appliances are left on unnecessarily, the system can significantly reduce energy waste and, in turn, the household's carbon footprint. This section of the scope involves calculating energy savings, analyzing efficiency improvements, and assessing the impact on reducing carbon emissions.

6. Sustainability and Environmental Impact

A broader element of the scope is the system's contribution to environmental sustainability. By optimizing energy use, the system helps reduce carbon emissions from households, which collectively contribute a significant portion of global energy consumption. The scope includes evaluating the potential for long-term environmental benefits, including reductions in overall energy demand and promoting a sustainable lifestyle. This evaluation will be critical to understanding the role that AI and IoT technologies can play in achieving global sustainability goals.

7. Expandability and Scalability

Although this project primarily focuses on light control, the system is designed to be scalable and adaptable to other appliances, such as fans, air conditioners, and heating systems. This expandability ensures that future versions of the system can control additional devices, further optimizing energy consumption across the entire household. The system can also be integrated with renewable energy sources such as solar panels, making it a future-ready solution for energy management. The scope, therefore, extends to evaluating the system's flexibility for future enhancements and its potential for wide-scale adoption in homes.

8.Testing and Validation

An important part of the scope involves the thorough testing and validation of the system in real-world environments. The system will be tested for its ability to accurately predict user behavior, efficiently manage energy usage, and reliably automate appliances. Testing will also assess the system's response time, energy savings, and user satisfaction. The validation process will provide insights into areas for improvement and further development. The scope also includes collecting feedback from users to refine the system for better performance and greater usability.

Introduction

With the growing concern over climate change and rising energy costs, optimizing energy consumption in residential areas has become crucial for sustainability. Homes are significant contributors to global energy demand, and inefficient energy use, particularly from household appliances, results in unnecessary energy waste and increased carbon emissions. Smart home technologies that combine IoT (Internet of Things) and AI (Artificial Intelligence) offer a promising solution to address these challenges by enabling more efficient energy management.

This research focuses on developing an intelligent home automation system that leverages both IoT and Generative AI (Gen AI) for personalized energy management. The system utilizes an ESP8266 microcontroller and various environmental sensors, such as the DHT11 (temperature and humidity), light sensors, and motion sensors, to monitor real-time conditions in the home. By analyzing this data, the AI model learns the occupants' habits and preferences, automating control of household appliances, particularly lighting, to reduce energy consumption without sacrificing comfort. For example, the system predicts when to turn lights on or off based on motion detection and ambient light levels, ensuring optimal use of energy.

The project integrates ThingSpeak, a cloud-based platform that enables users to monitor and control their home's energy usage remotely. By visualizing real-time data and automating appliance control, the system helps reduce energy waste and optimize energy use, thereby lowering the household's carbon footprint.

This paper outlines the design and implementation of the system, exploring its hardware, AI integration, and cloud communication. It also examines the system's potential to contribute to energy efficiency and environmental sustainability. By automating energy management intelligently, the system demonstrates how IoT and AI can transform homes into more eco-friendly and efficient environments.

Key Topics Covered:

- **IoT Architecture**: The hardware setup of the system, including sensors, microcontroller, and communication protocols.
- **Generative AI Integration**: How the AI learns user behavior from sensor data to predict and automate appliance control.
- **Automation Algorithms** : The process of automating lights based on occupancy and environmental light levels.
- **ThingSpeak Integration**: The role of ThingSpeak in visualizing real-time data and providing control over the automation system.

System Design and Working Process

Hardware Components

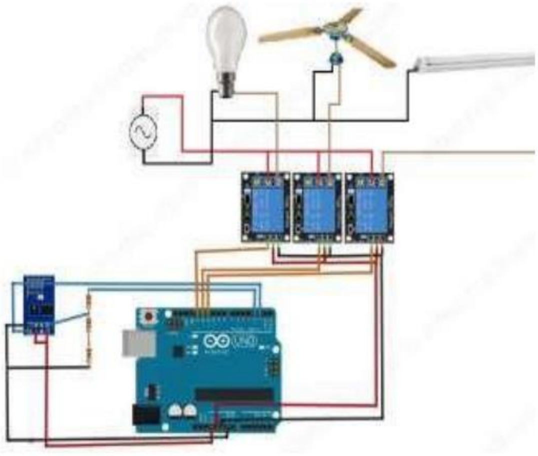
- **ESP8266 Microcontroller**:Acts as the central control unit, gathering data from sensors and communicating with ThingSpeak for real-time updates.
- **DHT11 Sensor**: Measures temperature and humidity levels in the home environment.
- **Light Sensor**: Detects ambient light levels, enabling light automation based on available daylight.
- **Motion Sensor (PIR)**: Detects human presence to automate turning lights on/off when occupants enter or leave the room.

Hardware Connections

- **ESP8266 to DHT11**: The DHT11 sensor is connected to one of the GPIO pins of the ESP8266 for temperature and humidity data collection.
- **ESP8266 to Light Sensor**:A photoresistor or LDR sensor connects to the ESP8266 to monitor natural light intensity.
- **ESP8266 to PIR Sensor**: The PIR sensor connects to the ESP8266, enabling it to detect motion and decide whether to switch lights on or off.

IoT and Cloud Communication

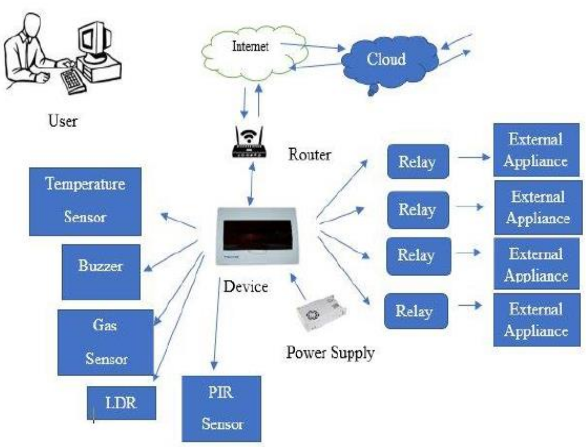
- **ThingSpeak**: The ESP8266 sends collected sensor data to ThingSpeak using HTTP requests. This cloud platform provides real-time data visualization and storage. The user can monitor sensor readings, track energy consumption, and control appliances through a web-based dashboard.



Working Mechanism

1. **Data Collection**: The ESP8266 gathers temperature, light, and motion data in real time from the connected sensors.
2. **Gen AI Processing**: The AI model analyzes historical data, learning the user's behavior and environmental patterns to predict when appliances should be turned on or off.
3. **Automation**: Based on AI predictions and sensor data, the system controls appliances, such as turning lights off when the room is vacant and adjusting light intensity based on ambient light levels.
4. **User Interface** : Data and system status are sent to ThingSpeak, where the user can view live updates and control settings through a user-friendly dashboard.

Methodology



The diagram illustrates the methodology for an intelligent home automation system that leverages IoT and cloud computing for managing appliances based on environmental conditions. Here's an explanation of the components and their roles in the system:

1. User Interface:

- The user, represented by a computer or mobile interface, interacts with the system via the internet. This interface allows the user to monitor and control appliances in the home environment.

2. Internet and Cloud Connectivity:

- **Router:** The system is connected to the internet through a router, which enables communication data to between the home automation system and the cloud.
- **Cloud Platform:** A cloud server (e.g., ThingSpeak or AWS IoT) stores the sensor data, processes it, and helps automate appliance control. The cloud also enables remote access and data analytics.

3. Sensors:

- **Temperature Sensor:** Monitors the room's temperature, sending data to the device (ESP8266 or microcontroller).
- **Gas Sensor:** Detects the presence of harmful gases in the environment, triggering alerts or automation (e.g., turning on ventilation).
- **LDR (Light Dependent Resistor):** Measures the ambient light levels, helping to control lighting automatically based on external light conditions.
- **PIR (Passive Infrared) Sensor:** Detects motion in a room to automate lights and appliances based on occupancy.
- **Buzzer:** Provides audio alerts for various scenarios, like detecting gas leaks or intrusions.

4. Device (Controller):

This central unit, typically an ESP8266 or similar microcontroller, gathers data from sensors and communicates with the cloud platform. It makes decisions about appliance control based on sensor input and cloud-based AI algorithms.

5. Power Supply:

The system includes a power supply unit that ensures continuous operation of the device and connected sensors.

6. Relays:

Relays are used to control external appliances like fans, lights, air conditioners, and other devices. These relays receive signals from the controller to switch appliances on or off.

7. External Appliances:

These are household devices that are controlled by the system. The control is automated based on the real-time data gathered from the environment and user preferences.

8. Data Flow:

- Sensors constantly monitor the environment and send the **Device (Controller)**.
- The **Controller** processes the sensor data, sends it to the **Cloud**, and follows instructions (or automates actions) based on pre-set logic and conditions (e.g., if the room is dark, turn on the light).
- The cloud platform provides additional functionality like remote access, data analysis, and long-term storage of sensor readings.
- **Relays** receive control signals from the controller to manage external appliances.

Advantages-

Energy Efficiency:

- The system optimizes energy consumption by automatically controlling appliances based on real-time data from environmental sensors. This helps reduce unnecessary energy use, leading to lower utility bills and decreased carbon emissions.

Enhanced Comfort:

- By learning user preferences and habits, the system adjusts the environment (e.g., lighting and temperature) to ensure maximum comfort. Users can also manually control appliances remotely, allowing for personalized living conditions.

Improved Safety:

- The integration of sensors such as gas and motion detectors enhances home safety. The system can trigger alerts or automatically turn on ventilation in case of gas detection, and use motion sensors to light up spaces when someone enters.

- **Data-Driven Insights:**

The cloud platform collects and analyzes data over time, providing users with insights into their energy consumption patterns and appliance usage. This information helps users make informed decisions about energy management and sustainability.

- **Convenience and Automation:**

The system automates routine tasks (like turning off lights when a room is unoccupied) and enables remote access and control through smartphones or computers. This level of automation simplifies daily routines and enhances user convenience.

Future Work

Integration of Additional Sensors:

Incorporate more sensors (e.g., humidity, CO_2) to enhance environmental monitoring and improve automation capabilities.

Advanced Machine Learning Models:

Develop more sophisticated AI algorithms to better predict user behavior and optimize energy consumption, potentially integrating reinforcement learning techniques.

User Personalization Features:

Enhance user interfaces with customizable settings and preferences, allowing for more tailored automation and control options.

Mobile Application Development:

Create a dedicated mobile application for improved user interaction, enabling real-time monitoring, control, and notifications directly from smartphones.

Scalability and Interoperability:

Expand the system to support more devices and appliances, ensuring compatibility with various IoT standards and protocols for broader adoption in smart homes

Acknowlegement

- **Project Supervisors:**
    - We extend our heartfelt thanks to our project supervisors for their guidance, support, and valuable insights throughout the development of this intelligent home automation system.
- **Research and Development Team:**
    - Special appreciation to the research and development team for their collaboration and technical expertise in integrating IoT and Gen AI technologies into the project.
- **Sensor and Hardware Providers:**
    - Acknowledgment to the manufacturers and suppliers of the sensors and hardware components (e.g., ESP8266, temperature, and motion sensors) that made the implementation of the system possible.
- **Cloud Service Providers:**
    - Gratitude to the cloud service providers for their infrastructure and services, which facilitated data storage and analysis, enhancing the system's functionality.
- **Test Participants:**
    - Thank you to all participants who provided feedback during the testing phase, helping us refine the system for better user experience and performance.
- **Family and Friends:**
    - Appreciation to family and friends for their unwavering support and encouragement throughout the project, which motivated us to achieve our goals.

Conclusion

The **Intelligent Home Automation System Using Gen AI and IoT for Personalized Energy Management** demonstrates the potential of integrating advanced technologies like artificial intelligence and the Internet of Things to create smart, energy-efficient homes. By utilizing real-time data from environmental sensors and learning user behavior, the system can intelligently automate appliances, reducing energy consumption and contributing to a lower carbon footprint.

The system's adaptability to user preferences enhances comfort while promoting sustainability. Through cloud integration, it provides users with valuable insights into their energy usage, encouraging further optimization.

Moving forward, this project opens the door to incorporating more advanced AI models and expanding the range of connected devices to create even more efficient and personalized automation systems. With ongoing improvements and testing, this innovative approach can be a significant step toward sustainable living, energy conservation, and reducing environmental impact on a broader scale.

References

1. Saha, H. N., Mandal, A., & Sinha, A. (2017). **Recent trends in the Internet of Things**. *Electronics, Communication, and Aerospace Technology (ICECA)*, IEEE, 1973-1978.
2. Kumar, R., & Rajasekaran, M. P. (2016). **An IoT-based smart home framework for the control of appliances**. *International Conference on Recent Trends in Information Technology (ICRTIT)*, IEEE, 1-4.
3. Al-Ali, A. R., Zualkernan, I. A., & Aloul, F. (2010). **A mobile GPRS-sensors array for air pollution monitoring**. *IEEE Sensors Journal*, *10*(10), 1666-1671.
4. Yan, Y., Qian, Y., Sharif, H., & Tipper, D. (2012). **A survey on smart grid communication infrastructures: Motivations, requirements, and challenges**. *IEEE Communications Surveys & Tutorials*, *15*(1), 5-20.
5. Javed, H., Larijani, H., & Ahmadinia, A. (2017). **Smart home energy management systems—A survey**. *Energies*, *10*(4), 635.
6. Li, J., & Fu, Y. (2014). **Research on intelligent home energy management system based on Zigbee technology**. *International Conference on Mechanical Engineering, Industrial Electronics and Information Technology*, 192-195.
7. Bonino, D., Corno, F., & De Russis, L. (2012). **Home energy consumption feedback: A user survey**. *Energy and Buildings*, *47*, 383-393.
8. Alam, M. R., Reaz, M. B. I., & Ali, M. A. M.

(2012). **A review of smart homes—Past, present, and future**. *IEEE Transactions on Systems, Man, and Cybernetics*, *42*(6), 1190-1203.

9. Khan, A., Mahmood, A., Safdar, A., Khan, Z. A., & Khan, N. A. (2016). **Load forecasting, dynamic pricing, and DSM in smart grid: A review**. *Renewable and Sustainable Energy Reviews*, *54*, 1311-1322.
10. Das, S. R., Paul, B. K., & Roy, A. (2020). **IoT-based intelligent energy management system for home automation**. *International Journal of Recent Technology and Engineering (IJRTE)*, 7(6), 11-15.
11. Babu, K., Anitha, R., & Suganya, S. (2018). **Energy efficient smart home automation systems using IoT and AI**. *Journal of Artificial Intelligence Research & Advances*, 15-20.
12. **A. Z. Alkar** and **U. Buhur**, **"An Internet based wireless home automation system for multifunctional devices,"** Consumer Electronics, IEEE Transactions on, vol. 51, pp. 1169-1174, 2005.
13. **Ejaz Ahmed, Ibrar Yaqoob, Abdullah Gani, Muhammad Imran,** and **Mohsen Guizani**,IEEE Wireless Communications "Internet-of-Things-Based Smart Environments: State of the Art, Taxonomy, and Open Research Challenges", 1536 1284,October 2016
14. **C. Chiu-Chiao, H. Ching Yuan, W. Shiau-Chin, and L. Cheng-Min,** "Bluetooth-Based Android Interactive Applications for Smart Living," in Innovations in Bio-inspired Computing and Applications (IBICA), 2011 Second International Conference on, 2011, pp. 309-312.
15. **G.Kortuem, F.Kawsar, D.Fitton, and V.Sundramoorthy**,"Smart objects as building blocks for the internet of things," Internet Computing, IEEE, vol. 14, pp. 44-51, 2010.
16. **Luca Mainetti, Vincenzo Mighali, Luigi Patrono** "An IoT-based Usercentric Ecosystem for Heterogeneous Smart Home Environments", IEEE ICC 2015 SAC - Internet of Things, pp. 704-709.
17. **M. A. Al-Qutayri and J. S. Jeedella**, "Integrated Wireless Technologies for Smart Homes Applications," in Smart Home Systems, M. A. Al-Qutayri, Ed., ed: InTech, 2010.
18. **Majed AlOtaibi and Lo'ai A. Tawalbeh, Yaser Jararweh**, "Integrated Sensors System Based on IoT and Mobile Cloud Computing", 978-1-5090-432,IEEE, 2016.
19. **Vidyasagar, K., Balaji, G., and Reddy, K. N. (2015).** Android Phone Enabled Home Automation. Journal of Academia and Industrial Research (JAIR) Vol.4, No. 2, pp 65.
20. **Y. Liu**, **"Study on Smart Home System Based on Internet of Things Technology**," in Informatics and Management Science IV. vol. 207, W. Du, Ed., ed: Springer London, 2013, pp. 73-81

APPENDIX III

PUBLICATION/

CONFERENCE CERTIFICATE

APPENDIX IV

CERTIFICATE OF COMPETITION/

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DEPARTMENT OF EMERGING TECHNOLOGIES (AI&ML)
To create competent and creative professionals in the field of Artificial Intelligence & Machine Learning to address the needs of industry and society

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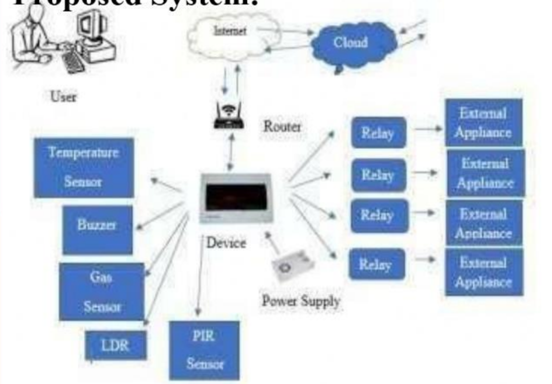
Abstract: This project aims to develop an advanced home automation system that leverages the power of Generative AI (Gen AI) and Internet of Things (IoT) technologies to create a personalized energy management solution. The system utilizes the ESP8266 microcontroller, along with various environmental sensors such as light, temperature, and motion detectors, to gather real-time data from the home environment. By analyzing this data, the Gen AI model will learn the habits and preferences of the household occupants, enabling it to predict and automate the control of household appliances. This intelligent system is designed to optimize energy consumption, enhance user comfort, and reduce the household's carbon footprint. The project highlights the potential of combining AI and IoT for sustainable and efficient living

Introduction:

The rising global focus on sustainability, energy conservation, and the reduction of carbon footprints has made energy efficiency a vital concern in modern homes. With increasing electricity demands and the environmental impact of excessive energy consumption, there is a need for smarter, more efficient systems that can optimize resource use while maintaining comfort. The advent of the Internet of Things (IoT) and Artificial Intelligence (AI) has opened new avenues for intelligent automation, transforming the way we interact with home environments. The Intelligent Home Automation System using Generative AI (Gen AI) and IoT offers a comprehensive solution that addresses the challenges of energy management in households. By leveraging IoT technologies, such as the ESP8266 microcontroller and environmental sensors, this system is capable of gathering real-time data from various points within the home, such as light, temperature, and motion sensors. This data provides a continuous stream of information about the living environment, which is crucial for understanding how energy is being consumed and where improvements can be made.The introduction of Generative AI further enhances the system by learning the habits, preferences, and behavior of the household occupants. This advanced AI model is designed to predict future actions, allowing the system to automate the control of household appliances in a way that optimizes energy use. By learning when and how appliances are used, the system can make decisions about when to activate or deactivate devices, thereby minimizing unnecessary energy consumption without compromising user comfort.

One of the key goals of this project is to reduce the household's carbon footprint by providing a smart, energy-efficient solution. This system is not only focused on automating everyday tasks but also on promoting sustainability by helping homeowners make more informed decisions about their energy usage. The system continuously adjusts its behavior based on the current environmental conditions and user habits, ensuring that energy is consumed in the most efficient manner possible.Additionally, the system integrates with ThingSpeak, a cloud platform that allows for real-time monitoring and control of data. Users can access the platform via a user-friendly interface to track the system's performance, review energy consumption insights, and manually override automated settings when needed. This creates a feedback loop that allows the system to constantly learn and improve while providing valuable information to the user.

Proposed System:



Conclusion and Future scope:

Conclusion:

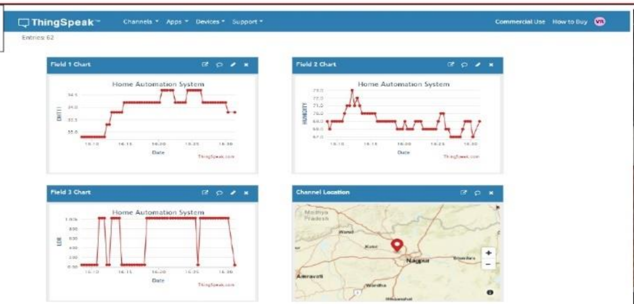
The **Intelligent Home Automation System** successfully demonstrates the potential of integrating **Generative AI** and **IoT** to optimize energy management in households. By learning user behaviors and controlling appliances in real-time, the system significantly reduces energy consumption while maintaining user comfort. Its ability to adapt to real-time environmental conditions ensures efficient operation, contributing to both convenience and sustainability.

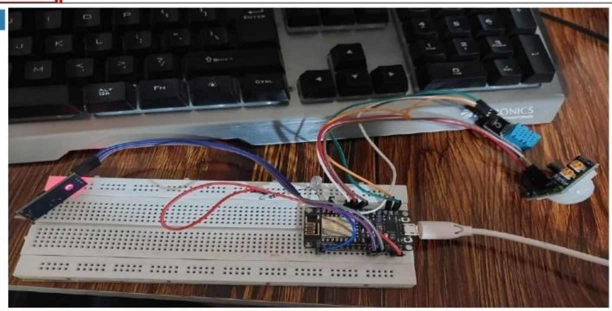
Looking ahead, the system's framework can be expanded to incorporate more advanced AI models and additional IoT devices, further enhancing energy optimization and user customization. This project not only promotes energy savings but also serves as a model for future smart home systems aimed at reducing carbon footprints and promoting eco-friendly living.

Future Scope:

The future scope of the **Intelligent Home Automation System** includes integrating renewable energy sources like solar panels, enhancing the AI model for deeper predictive analytics, and expanding the range of IoT sensors to monitor additional environmental factors such as air quality and water usage. The system can also be scaled for use in larger environments, such as smart buildings and communities, and integrated with emerging smart grid technologies to further optimize energy consumption and contribute to a more sustainable and eco-friendly future.

Result:





References:

1. K. A. A. Omar, et al., "Artificial Intelligence in Smart Home Systems: A Survey," *IEEE Access*, vol. 10, pp. 8536-8551, 2022.
2. M. H. N. Nguyen, et al., "Energy Efficiency in Smart Homes: A Comprehensive Review," *Energy Reports*, vol. 9, pp. 1205-1221, 2023.
3. J. J. Li, et al., "Generative Adversarial Networks for Energy Management in Smart Grids: A Survey," *IEEE Transactions on Smart Grid*, vol. 14, no. 3, pp. 1800-1812, 2023.
4. A. A. Khalifeh, et al., "A Survey on Internet of Things: Architecture, Applications, and Challenges," *Future Generation Computer Systems*, vol. 112, pp. 945-964, 2021.
5. S. Kumar, et al., "IoT-Based Smart Home Automation System Using Generative AI," *Journal of Ambient Intelligence and Humanized Computing*, vol. 12, pp. 1189-1198, 2021.
6. L. P. Qian, et al., "AI-Driven Energy Management in IoT-Based Smart Homes," *IEEE Internet of Things Journal*, vol. 8, no. 5, pp. 3470-3482, 2021.
7. R. Z. Haye, et al., "A Study on Smart Home Energy Management Systems Using Machine Learning Techniques," *IEEE Transactions on Consumer Electronics*, vol. 67, no. 4, pp. 2904-2914, 2021.
8. F. H. Farzan, et al., "IoT-Based Energy Efficiency Monitoring System for Smart Homes," *Journal of Energy Management*, vol. 7, no. 2, pp. 93-105, 2022.

APPENDIX V

PPT HANDOUTS

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Mr. Ayush Roy
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Under the Guidance of
Prof. Yogesh Narekar

Session:2024-25 (ODD)
Department of Emerging Technologies (AI&ML and AI&DS)

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PROJECT OVERVIEW

This project aims to develop an advanced home automation system that leverages the power of Generative AI (Gen AI) and Internet of Things (IoT) technologies to create a personalized energy management solution. The system utilizes the ESP8266 microcontroller, along with various environmental sensors such as light, temperature, and motion detectors, to gather real-time data from the home environment. By analyzing this data, the Gen AI model will learn the habits and preferences of the household occupants, enabling it to predict and automate the control of household appliances. This intelligent system is designed to optimize energy consumption, enhance user comfort, and reduce the household's carbon footprint. The project highlights the potential of combining AI and IoT for sustainable and efficient living.

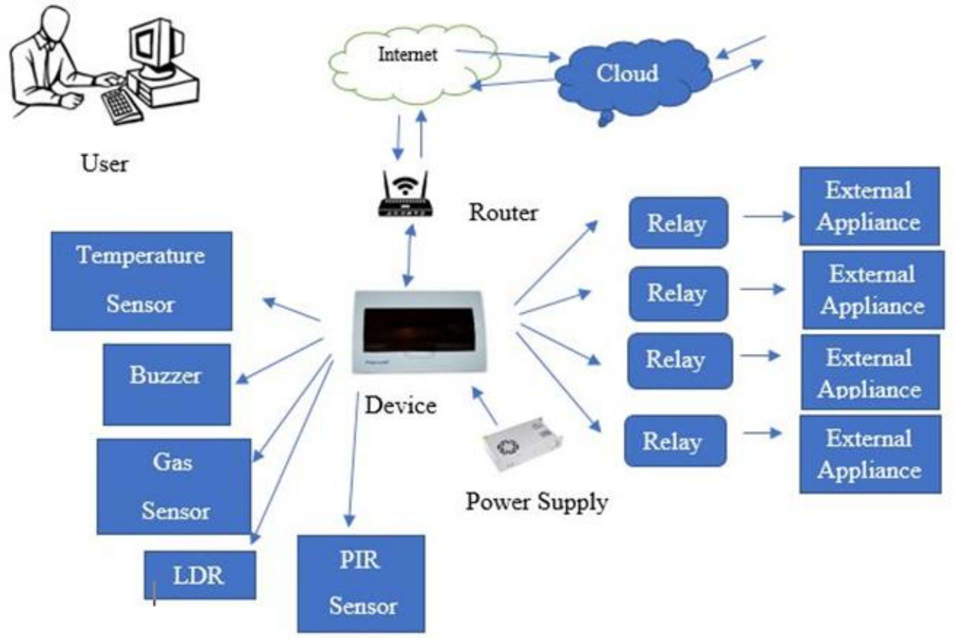
Project Objectives

- Implement IoT-enabled sensors and devices to continuously monitor energy consumption patterns and environmental conditions within the home.
- Design and integrate automated controls that adjust energy settings in real time, ensuring maximum efficiency without compromising comfort.
- Design the system to be scalable and adaptable to different household sizes and types, ensuring broad applicability and ease of implementation.
- Develop a user-friendly interface that provides tailored suggestions for optimizing energy use, such as adjusting heating, cooling, and lighting settings based on occupancy and individual habits.
- Ensure seamless connectivity and interoperability among various smart home devices to create a cohesive energy management ecosystem.

LITERATURE REVIEW

Literature Survey Papers	Background Information	Related Work
1. **"Artificial Intelligence in Smart Home Systems: A Survey"** by K. A. A. Omar et al. (2022).	**Home Automation Evolution**: Modern systems leverage IoT and AI for real-time data collection and control.	**IoT in Home Automation**: Integration of IoT devices like ESP8266 for monitoring and controlling home environments.
2. **"Energy Efficiency in Smart Homes: A Comprehensive Review"** by M. H. N. Nguyen et al. (2023).	**Generative AI**: Models predict behavior and optimize energy use by learning from data.	**AI for Energy Optimization**: Machine learning algorithms predict and optimize energy usage patterns.
3. **"Generative Adversarial Networks for Energy Management in Smart Grids: A Survey"** by J. J. Li et al. (2023).	**Energy Management & Carbon Footprint**: Strategies for reducing consumption and carbon footprint while maintaining comfort.	**Generative AI in Predictive Modeling**: GANs for creating predictive models in home automation.

METHODOLOGY



- IoT Architecture: The hardware setup of the system, including sensors, microcontroller, and communication protocols.
- Data Collection: The ESP8266 gathers temperature, light, and motion data in real time from the connected sensors.
- Gen AI Processing: The AI model analyzes historical data, learning the user's behavior and environmental patterns to predict when appliances should be turned on or off.
- Automation: Based on AI predictions and sensor data, the system controls appliances, such as turning lights off when the room is vacant and adjusting light intensity based on ambient light levels.
- User Interface: Data and system status are sent to ThingSpeak, where the user can view live updates and control settings through a user-friendly dashboard.
- Testing and Validation :An important part of the scope involves the thorough testing and validation of the system in real-world environments.

TOOLS AND TECHNOLOGIES USED

❑ Hardware:-
Microcontroller: ESP8266 (Nodemcu)
Sensors: Light (LDR sensor)
Temperature (DHT11 sensor)
Motion (PIR sensor)

❑ Programming Languages: C++ (for ESP8266)

❑ Software:-
Frontend: HTML, CSS
Backend:PHP/MySQL (CURD Operation)

❑ Cloud Platform:- Thingspeak (MATLAB)

PROGRESS SO FAR

Completed Tasks:
- ✓ Hardware Setup Complete: ESP8266 and sensors are assembled.
- ✓ Sensor Connections Established: DHT11, PIR, and LDR are connected.
- ✓ Programming has been completed with thingspeak connection.
- ✓ ThingSpeak Integration: Data is being sent to ThingSpeak for monitoring.

Challenges Faced:
- ❑ Ensuring stable communication between sensors and ESP8266.
- ❑ Debugging hardware setup issues and refining data collection protocols.
- ❑ Reliability: For home automation to succeed, developers should address considerations regarding the dependability of sensible devices compared with ancient home appliances and equipments.
- ❑ Date Collection and Use: Many connected home and smart products rely on value propositions that are in part about new functionality, and in part about the 'smarter' use of resources. In order to achieve this, data flows between the devices and servers operated by the device providers, between devices, and to and from the consumer's smart phone or computer.

FUTURE WORK

1. Integration of Additional Sensors: o Incorporate more sensors (e.g., humidity, CO2) to enhance environmental monitoring and improve automation capabilities.
2. Advanced Machine Learning Models: o Develop more sophisticated AI algorithms to better predict user behavior and optimize energy consumption, potentially integrating reinforcement learning techniques.
3. User Personalization Features: o Enhance user interfaces with customizable settings and preferences, allowing for more tailored automation and control options.
4. Mobile Application Development: o Create a dedicated mobile application for improved user interaction, enabling real-time monitoring, control, and notifications directly from smartphones.
5. Scalability and Interoperability: o Expand the system to support more devices and appliances, ensuring compatibility with various IoT standards and protocols for broader adoption in smart homes.

CONCLUSION

The "Intelligent Home Automation System Using Gen AI and IoT for Personalized Energy Management" project aims to create a smart home solution that combines Generative AI with IoT technology to optimize energy usage and reduce carbon footprints. By integrating ESP8266 microcontrollers with various environmental sensors and developing a robust web application, the system will collect real-time data, learn user preferences, and automate appliance control. This approach promises enhanced energy efficiency, user comfort, and environmental sustainability. The project's successful implementation will demonstrate the significant potential of combining AI and IoT for creating smarter, greener homes.

REFERENCES

Papers:

1. **"Artificial Intelligence in Smart Home Systems: A Survey"** by K. A. A. Omar et al. (2022).
2. **"Energy Efficiency in Smart Homes: A Comprehensive Review"** by M. H. N. Nguyen et al. (2023).
3. **"Generative Adversarial Networks for Energy Management in Smart Grids: A Survey"** by J. J. Li et al. (2023).

Books:

- **Internet of Things (IoT): A Hands-On-Approach: Bhaskar Krishnamachari (2017)**
- **Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play: David Foster (2021)**
- **Smart Home Automation with Linux and Raspberry Pi: Steven Goodwin (2017)**

Websites:

- https://youtu.be/UixNfOySIsA?si=di945udoLwZjVGCl
- https://youtu.be/kyuo0JpZtBE?si=RK8MOlR_n6TiXKQs
- https://youtu.be/aTFpYflYOG4?si=KMt4hs-NPW36Etr1

Thank You

APPENDIX VI

USER MANUAL

User Manual

On

"Intelligent Home Automation System Using Gen AI and IoT for Personalized Energy Management to Reduce Carbon Footprint"

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1. Overview

As we all know people loves to travel, no matter what season, what place it is, they just need a proper direction to travel. So, here is our web application Wanderer's Pabulum, that will guide throughout the journey, a tourist can explore places according to states and in that the places will be distinct according to users choice such as beaches, religious, heritage, hill stations, etc. A user can get to know about the famous local food of that specific state, as well as they will get to know the essence of Indian states, that how they are culturally diverse according to their festivals, traditions, attire, historical importance, uniqueness and many more. Unlike other countries India is a diverse country, it has different religions, each religion has different way of worshiping their God, that's why tourist get to see different sculptures, having different architecture showing their own significance and historical importance about it.

2. Aim

Intelligent Home Automation System Using Gen AI and IoT for Personalized Energy Management to Reduce Carbon Footprint

3. Objectives

- ✓ Implement IoT-enabled sensors and devices to continuously monitor energy consumption patterns and environmental conditions within the home.
- ✓ Design and integrate automated controls that adjust energy settings in real time, ensuring maximum efficiency without compromising comfort.
- ✓ Design the system to be scalable and adaptable to different household sizes and types, ensuring broad applicability and ease of implementation.
- ✓ Develop a user-friendly interface that provides tailored suggestions for optimizing energy use, such as adjusting heating, cooling, and lighting settings based on occupancy and individual habits.

4. Proposed Approach

The proposed intelligent home automation system is designed to reduce carbon footprints by using AI and IoT in the following ways:

1. Personalized Energy Management: The system will dynamically adjust energy consumption based on user-specific preferences and real-time data, ensuring that no energy is wasted. For example, it could reduce the use of air conditioning when the user is not at home.

2. Predictive Analytics: By using predictive models, the system can anticipate energy needs and prepare accordingly. It will suggest actions like pre-cooling the house before peak energy rates or using renewable energy sources when available (e.g., solar panels).

3. Energy Usage Insights: The system will generate detailed reports on energy usage patterns and offer insights into how users can further reduce their consumption.

4. Integration with Renewable Energy: If the household uses renewable energy sources such as solar panels, the system will prioritize the use of clean energy and manage battery storage efficiently to minimize reliance on grid power.

5. Carbon Footprint Monitoring: The system will track carbon emissions saved through optimized energy management and provide regular updates to users on their environmental impact.

5. Software Requirements

- **OS** – Windows 10
- **Modelling and Implementation tool** – ThingSpeak
- **IDE** – Ardiuno IDE
- **Language** – C++
- **Designing tool** – Blynk App

6. Hardware Requirements

Microcontroller: NodeMCU (ESP8266) or ESP322

Relay Module: 2-channel or 4-channel relay module (5V)

Sensors: DHT11 or DHT22 (temperature and humidity)2, LDR (light sensor), PIR (Motion Sensor), Power Supply: 5V power supply or battery (depending on your setup)

ESP8266 to DHT11: The DHT11 sensor is connected to one of the GPIO pins of the ESP8266 for temperature and humidity data collection.

ESP8266 to Light Sensor:A photoresistor or LDR sensor connects to the ESP8266 to monitor natural light intensity.

ESP8266 to PIR Sensor: The PIR sensor connects to the ESP8266, enabling it to detect motion and decide whether to switch lights on or off.

Breadboard and Jumper Wires: For making connections

Home Appliances: Lights, fans, or other devices you want to control.

7. Flowchart:-

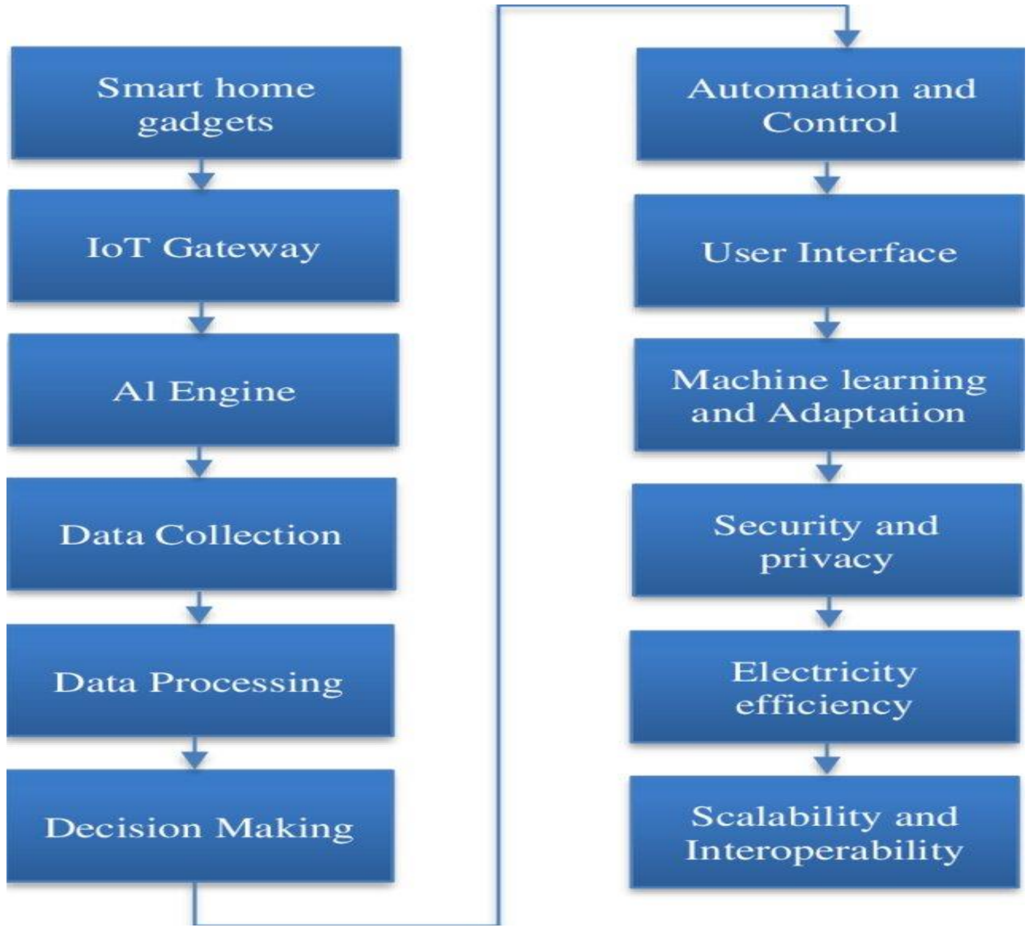


Figure 7.1 Flow Chart

8.Steps to Run the Project

System Design and Setup:

- Install IoT devices (smart meters, sensors, actuators, etc.) in the home.
- Deploy energy management components (e.g., smart thermostats, lighting, and appliance controls).

Data Collection:

- Gather real-time data from IoT sensors (temperature, humidity, energy consumption, occupancy).
- Collect user preferences and historical energy usage patterns.

Integration with Gen AI:

- Train AI models on energy consumption patterns and user behavior.
- Use generative AI to create personalized energy-saving strategies.

Prediction and Optimization:

- Predict energy demands using AI algorithms.
- Optimize energy usage by scheduling appliances during off-peak hours and reducing wastage.

Personalization:

- Generate user-specific recommendations for efficient energy use (e.g., adjust thermostat settings).
- Adapt settings based on changing behaviors or preferences.

Automation:

- Automate energy-efficient operations like turning off unused devices.
- Enable dynamic responses to environmental changes (e.g., adjusting blinds based on sunlight).

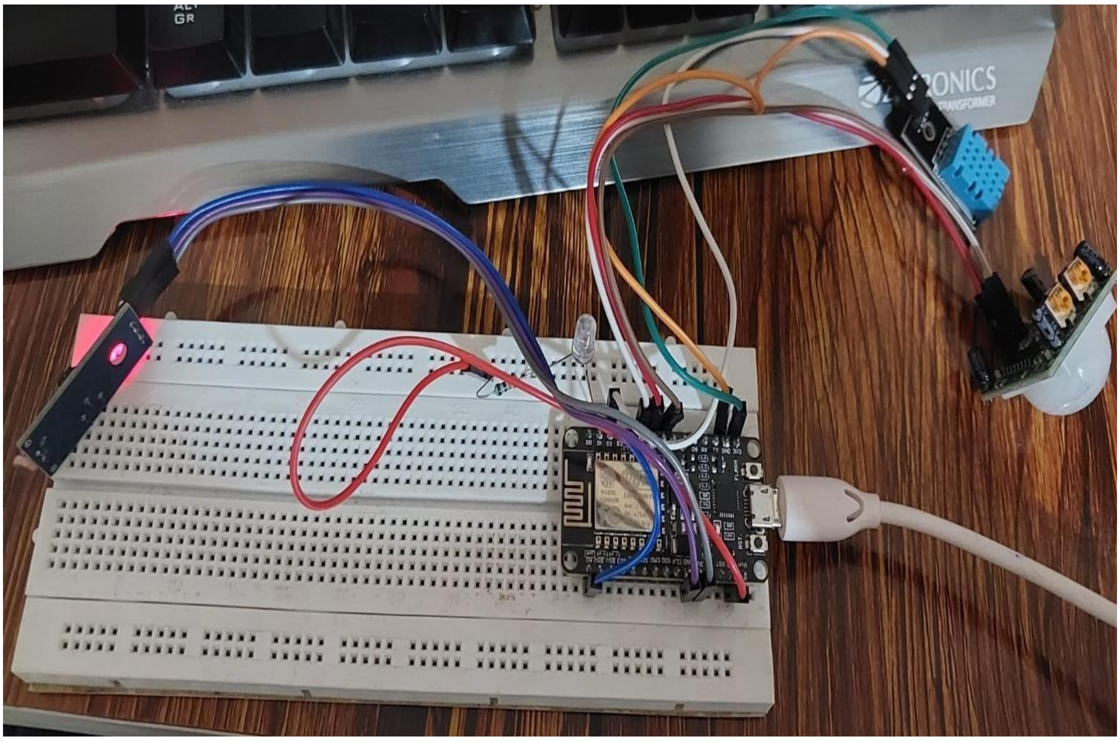
Carbon Footprint Reduction:

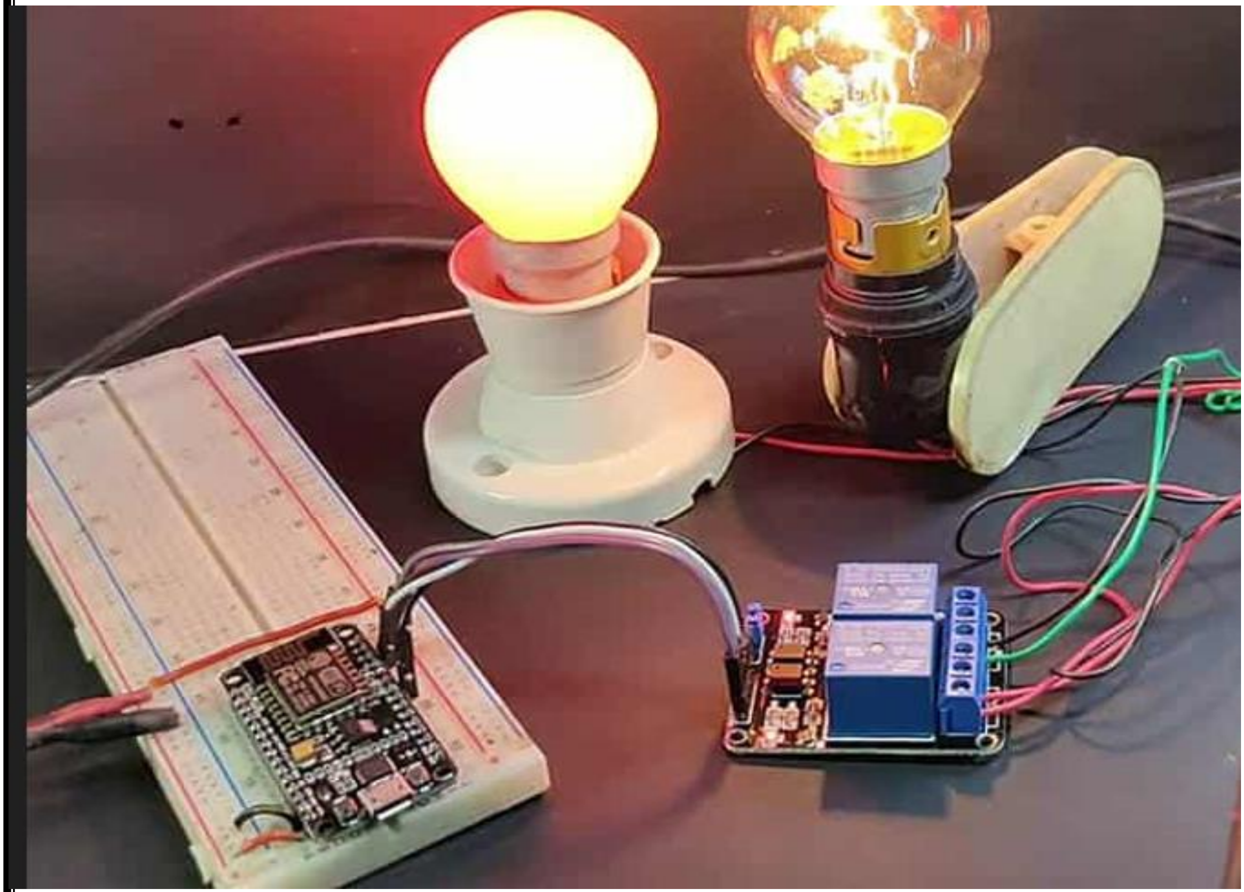
- Monitor and display real-time energy usage and carbon footprint metrics.
- Implement AI-driven suggestions to further minimize energy waste.

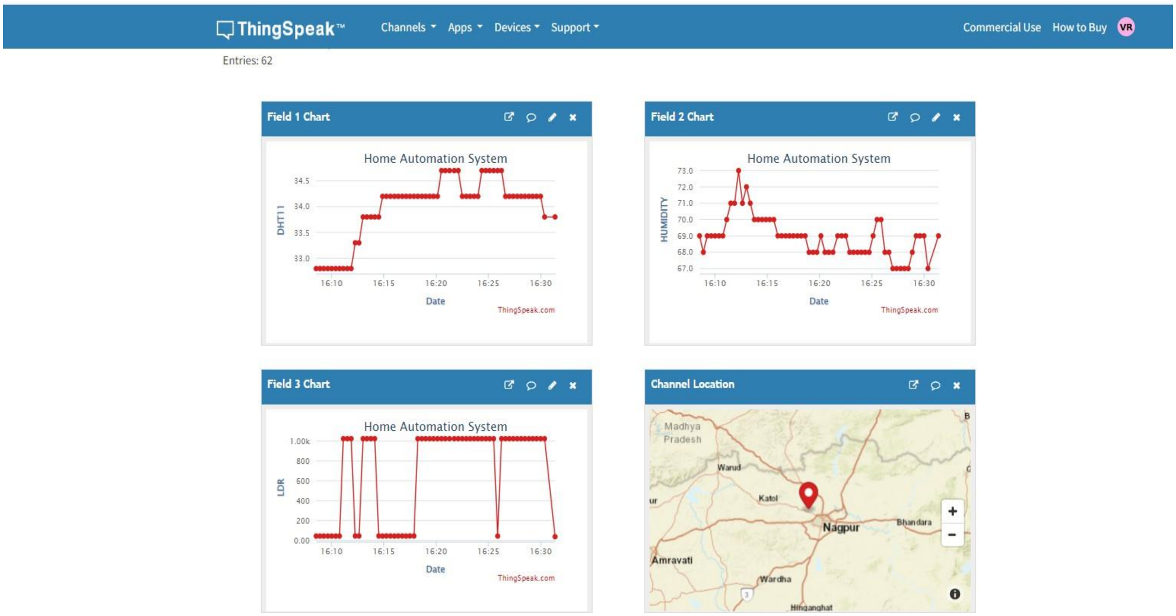
User Feedback and Continuous Learning:

- Gather user feedback to refine AI models.
- Continuously update and enhance the system for improved energy management.

9. Output/ Graph/Observations







10.Project Outcome

CO 1:- Apply: System offered tailored recommendations for energy-saving habits based on individual usage patterns.

CO 2:-Evaluate: Validated the integration of Generative AI for real-time scenario modeling and energy-saving simulations.

CO 3:-Apply: Decreased reliance on non-renewable energy sources by integrating solar, wind, or other sustainable energy inputs.

CO 4:-Analyze: Achieved significant reductions in energy consumption through dynamic control of devices based on real-time data.

CO 5:-Create: Innovate, design & develop systems to address real life problems and engagein life- long learning in continuing professional development.

11.PO and PSO Mapping

CO Code	Program Outcomes (POs)												Program Specific Outcomes (PSOs)	
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3		1	2	2	1	1				2	3	1
CO2	3	3		3	2	1						2	2	1
CO3	3	3	3		2	1	1	3	3		3	2	3	2
CO4	3	3		1						3			1	
CO5	2	2	3		3	1		1		2	2	3	3	3
AVG														

9. Future Scope

1. **Enhanced Machine Learning Algorithms**: As machine learning techniques evolve, integrating more sophisticated algorithms can improve the accuracy of energy predictions and recommendations. Continuous learning models that adapt based on user feedback and changing behaviors will enhance system responsiveness.

2. **Integration with Renewable Energy Sources**: Future systems could seamlessly integrate with solar panels, wind turbines, and other renewable energy sources. This would enable homeowners to optimize the use of clean energy, manage energy storage solutions, and reduce reliance on grid power, further decreasing carbon footprints.

3. **Smart Grid Connectivity**: Connecting home automation systems to smart grids can facilitate real-time energy trading and load balancing. Homes could participate in demand-response programs, receiving incentives for reducing energy consumption during peak periods.

10.Limitations

1. **Data Quality and Quantity:** Accurate AI predictions depend on the quality and quantity of data. Insufficient or biased data from IoT devices may lead to suboptimal energy management recommendations.
2. **Interoperability Issues:** IoT devices from different manufacturers may lack standardization, making integration challenging. This can hinder seamless communication and coordination between devices.
3. **Energy Usage Forecasting:** Gen AI models may struggle with accurate energy usage forecasting in cases of irregular or unpredictable user behavior.
4. **Latency and Processing Delays:** Real-time processing and decision-making might be affected by latency, especially if the system relies on cloud-based computing rather than edge computing.