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Integrating IoT for Smart Home Automation: Enhancing Energy Efficiency, Security, and System Optimization

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Abstract - The low-cost, Internet of Things-based home automation system presented in this study is intended to help the elderly and those with disabilities. Wireless control of home appliances, including fans, lights, heating, cooling, and security systems, is made possible by the system's use of the Node MCU microcontroller with integrated Wi-Fi. Users can remotely operate devices via the internet with ease thanks to an easy-to-use Android app. The technology reduces the requirement for continual human intervention by supporting both manual control and autonomous operation depending on environmental variables. The system is incredibly accessible and practical because it can be accessed from any location thanks to a cloud-based server. To guarantee seamless control, many devices communicate with the Node MCU using various transmission modalities. This smart home solution is simple to install and use, and it enhances comfort, safety, and convenience. The Android platform offers real-time appliance status updates. All things considered, the project provides a scalable, effective, and user-friendly method of modern home automation that improves quality of life, particularly for the elderly and people with disabilities.

Key Words: Internet of Things (IoT), cloud-based server, microcontroller, Node MCU, home automation, Wi-Fi

1.INTRODUCTION

Home automation has quickly changed in the last few years from being a luxury idea to a useful and affordable option for contemporary life. Using technology to remotely or automatically operate home systems and appliances improves convenience, security, and energy savings. Homeowners may now use voice commands to control lighting, heating, entertainment systems, and even security features thanks to the proliferation of smart devices and speech-activated assistants. Among the many platforms accessible, Google Assistant is unique because of its strong artificial intelligence capabilities and smooth integration with a variety of smart devices.

This research paper explores the implementation of a home automation system using Google Assistant as the central control interface. The system aims to demonstrate how everyday tasks can be streamlined through voice commands and mobile applications, significantly improving the quality of life. The study focuses on designing a cost-effective, user-friendly, and scalable automation setup that leverages Google Assistant's natural language processing and IoT compatibility. By analysing the technical requirements, system architecture, and practical use cases, this project provides valuable insights into the future of smart homes.

2. LITERATURE REVIEW

The integration of **Internet of Things (IoT)** technology into **home automation** has significantly advanced the way people interact with their living spaces, providing increased comfort, security, energy efficiency, and convenience. Over the past decade, various research papers have explored the application of IoT in smart homes, with a focus on energy efficiency, security, and overall optimization of daily tasks. This literature review analyses key research studies in the field of IoT-based home automation systems, specifically focusing on **energy efficiency**, **security enhancements**, and **optimization techniques**.

Vishwakarma et al. (2021) propose a smart **energy-efficient home automation system** that integrates **IoT** technology to control home appliances and reduce energy consumption. The system uses a **Node MCU microcontroller** to connect household devices to the internet and remotely manage their operation. The core objective of the paper is to create a **multimodal IoT-based control system** that optimizes energy use while providing users with remote control options via a smartphone application or voice commands through **Google Assistant**.

The study focuses on the design and implementation of a smart home system that is highly dependent on **Wi-Fi connectivity** to ensure constant communication between devices. **IFTTT (If This Then That)** is used to interpret voice commands, while **MQTT (Message Queuing Telemetry Transport)** protocol is implemented via **Adafruit** to establish seamless communication between the devices and the server. The **Arduino IDE** is utilized for programming the Node MCU to ensure compatibility and reliability.

The system also integrates an **auto power backup** feature to ensure uninterrupted service during power failures. The energy efficiency aspect is addressed by monitoring device usage in real time and adjusting the operation based on user preferences or energy consumption patterns.

Somani et al. (2020) present a dual-function **IoT-based home automation system** that not only automates home appliances but also integrates **home security** features. The system is designed to provide an easy-to-use interface via an **Android application**,

which transforms the smartphone into a remote control for all home devices. The key security feature includes **motion sensors** that detect unauthorized movements at the entrance of the house and trigger an alert system that sends notifications along with images of the entrance to the homeowner in real time.

The authors implement **Raspberry Pi** as the main server to handle communication between devices, sensors, and the user application. The system consists of two modules: a **home automation module** (for controlling devices like fans, lights, and doors) and a **security module** (incorporating motion sensors, smoke detectors, and a camera). The use of motion sensors ensures that potential intrusions are immediately detected, while the camera provides visual verification, allowing the homeowner to act if necessary.

The use of real-time notifications via the app ensures prompt responses to security threats, making the system not just a tool for convenience but also a critical component for home safety.

Churasia and Jain (2021) introduce an innovative approach to smart home automation by reducing **computational overhead** in existing IoT systems that use multiple encryption techniques. Traditional smart home systems often rely on encryption algorithms like **AES** (Advanced Encryption Standard) or **ECHD** (Elliptic Curve Diffie-Hellman) to secure communications, but these encryption methods can create performance bottlenecks and high computational loads, particularly in resource-constrained devices.

To overcome this challenge, the authors propose a system that minimizes cryptographic operations while ensuring **strong security** by connecting devices directly to a **real-time broker cloud**. This approach bypasses the need for intermediary gateways, thus reducing the computational complexity. The system uses **sensor-based learning**, which allows devices to **automatically configure themselves** without human intervention based on real-time data. The focus is on **temperature sensing**, although the system is flexible enough to accommodate other types of sensors, such as humidity or motion sensors.

By integrating a **real-time cloud broker**, the system ensures efficient and secure communication between devices while bypassing the overhead of traditional encryption algorithms. This method not only improves the system's performance but also enhances the overall security of data transmission between the user and the smart home devices.

3. METHODOLOGY

3.1 Proposed Home Automation System

Customers can sign in to the machine using their PC or mobile device. A basic test is conducted to determine whether the equipment instrument is turned on. Handiest only if the device is authorized and operational, in which case the person is validated. Once the validation is completed correctly, the person is prepared to send control alarms to the machine. The SL intended power program at the equipment gadget will always follow for the change inside the distinction and will carry the markers to the circuit as a result. When a customer selects a non-public exchange for any instrument [i.e., ON or off], the records is transmitted in a string format from the handheld to the web server, where the website serves as the host. The status is saved in the database of their non-open device field. In a reasonable example, the circuit power program on the equipment end uses a webpage to restore the devices' renown [every 10 seconds]. These modifications are saved on the PC inside the web site's name and are quite similar to treatments [transient web files] from the web server. Consequently, every ten seconds, as the website is refreshed and the new treat values are updated.

3.2 Block Diagram of System

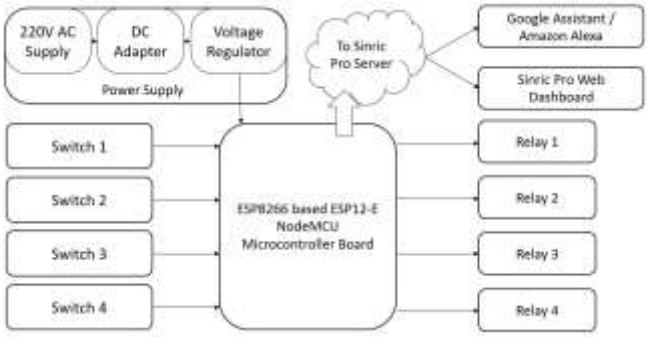


Fig -1: Block Diagram of the Proposed System

In our home automation system, we have shown how we can control two devices using internet of things (IOT). There are two sorts of correspondence engaged with this venture: wired and remote correspondence. We have used remote communication to operate the device using internet of things. Figure 1 depicts the picture of our model.

3.3 Circuit Diagram of System

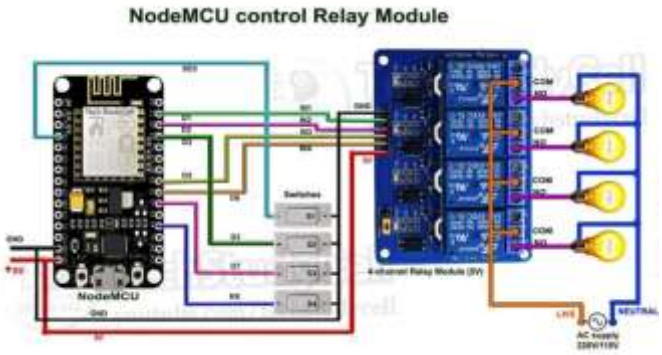


Fig -2: Circuit Diagram of System

4. HARDWARE COMPONENTS

The main components has been used to construct this project are Node MCU ESP8266, Relay Module, Simple switches, Connecting Component, Electric Appliances, Power Supply.

4.1 Node MCU ESP8266

The Node MCU ESP8266 development board comes with the ESP-12E module containing ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable

clock frequency. Node MCU has 128 KB RAM and 4MB of Flash memory to store data and programs. Its high processing power with in-built Wi-Fi / Bluetooth and Deep Sleep Operating features make it ideal for IoT projects. Node MCU can be powered using Micro USB jack and VIN pin (External Supply Pin). It supports UART, SPI, and I2C interface.

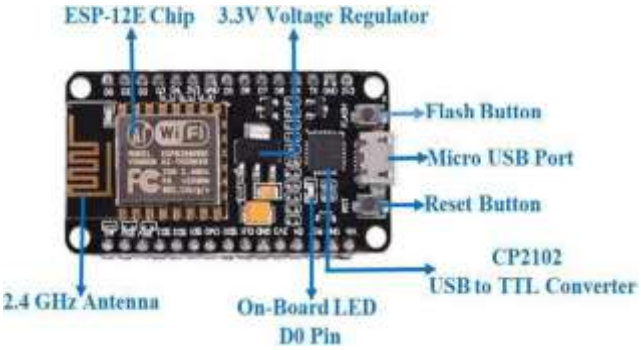


Fig 3: NodeMCU ESP8266

4.2 Relay Module

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. A relay is an electrically operated device. It has a control system and (also called input circuit or input contactor) and controlled system (also called output circuit or output cont. actor). It is frequently used in automatic control circuit. To put it simply, it is an automatic switch to controlling a high-current circuit with a low-current signal.

Fig 4: Single Relay Module

4.3 Simple switches

Simple switches, in the context of the Node MCU Home Automation Project, refer to basic electrical switches that are manually operated to control the switching of electrical appliances or devices. These switches typically consist of a mechanical lever or button that, when pressed or toggled, completes or interrupts an electrical circuit, thereby turning the connected appliance or device on or off. In the Node MCU Home Automation Project, simple switches serve as a user interface for manual control of the connected electrical appliances or devices. They are wired in parallel with the relay modules connected to the Node MCU ESP8266 microcontroller board. When a switch is toggled or pressed, it sends a signal to the Node MCU board, which then triggers the corresponding relay to either close or open the circuit, thereby turning the connected appliance on or off.

Fig 5: Simple Switches

4.4 Connecting Component

These are commonly called as jumper wires these allows an electrical current or signal to travel from one point on a circuit to another because the signal or current needs a medium through which to move. Connecting wires are made with copper from the inside with rubber insulation because copper is a very good conductor and rubber is a very good insulator. They are designed with such length and thickness which is ideal for connecting electronic circuits and operate on their corresponding voltages.

4.5 Electric Appliances

In this project, a light bulb is used as the main electrical appliance to demonstrate smart control functionality. The bulb acts as a load that can be turned on or off remotely through voice commands given to Google Assistant, showcasing the integration of IoT with everyday household devices. This setup not only highlights the convenience of automated lighting but also represents how traditional electrical appliances can be enhanced with modern smart technology for improved energy efficiency and user comfort.

5. SOFTWARE COMPONENTS

In this project we used Google Home app, Alexa, Sinric Pro API and Arduino IDE as programming interface.

5.1 Arduino IDE

The ATMega328p microcontroller IC with Arduino bootloader makes a lot of work easier in this project as Arduino code is written in C++ with an addition of special methods and functions, which we'll mention later on. C++ is a human-readable programming language. When you create a 'sketch' (the name given to Arduino code files), it is processed and compiled to machine language. The Arduino Integrated Development Environment (IDE) is the main text editing program used for Arduino programming. It is where you'll be typing up your code before uploading it to the board you want to program. Arduino code is referred to as sketches.

5.2 Google Assistant

Google Assistant is a virtual assistant developed by Google, capable of performing various tasks and responding to user commands through voice interaction. It is accessible on a wide range of devices, including smartphones, smart speakers, displays, and other smart home devices. Google Assistant uses natural language processing and artificial intelligence to understand and execute user requests, providing personalized assistance and access to a vast array of services, information, and smart home controls.

The function of Google Assistant in a Node MCU home automation project is to enable voice controlled operation of smart home devices and systems. Users can issue voice commands to Google Assistant to perform actions such as turning

lights on or off, adjusting thermostat settings, controlling smart appliances, or activating custom routines configured within the Node MCU based home automation system.

Fig 6: Google Assistant

5.3 Sinric Pro

Sinric Pro is a cloud-based platform that allows for seamless integration of smart home devices with voice assistants such as Amazon Alexa and Google Assistant. It provides an easy-to-use API that enables developers to connect their IoT devices to the Sinric Pro platform, allowing users to control these devices using voice commands through Alexa or Google Assistant

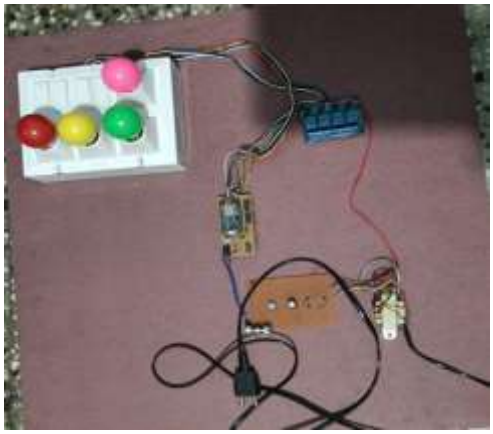
In a the home automation project, Sinric Pro can be utilized to add voice-controlled functionality to the smart home system. By integrating Sinric Pro with the Node MCU board, users can interact with their home automation devices using voice commands spoken to their Alexa or Google Assistant-enabled devices.

Fig 7: Sinric Pro

6. OPERATION AND WORKING

The proposed system offers versatile control options, including voice commands, a dedicated mobile application, web-based API integration via Sinric Pro, and manual interfacing. Devices were systematically configured using the Sinric Pro API, incorporated into our software logic, and programmed onto the Node MCU microcontroller. This configuration enables seamless, real-time control of hardware components over the internet. Central to voice-based control is the integration with Google Assistant, accessible through Google Home and compatible devices. Upon establishing an internet connection, users can interact with the system by issuing commands prefixed with "OK Google" or "Hey Google," enabling intuitive and hands-free operation—for instance, a command like “turn on Relay one” activates the corresponding relay module. Accurate device naming within the API is essential to ensure precise recognition and response by Google Assistant. While Google Home serves as an effective voice interface, its functionality is significantly restricted in the absence of an internet connection.

7. RESULT ANALYSIS



The framework going for delicate products is the looking at achieved on an outright, included machine to assess the machine's congruity with its exact necessities. gadget testing would also fall inside the range of the dark compartment looking at, and in this way, it must need no data around the interior structuring of the presence of mind or the code. It's miles a totally comparable deliberate check case lettering. inside the check case lettering we ought to be equipped for compose the check case circumstances and moreover the utilization cases.

8. CONCLUSION AND FUTURE RECOMMENDATIONS

8.1 Conclusion

As this endeavor has progressed, we have learned a great deal about the several modules being used for this task. We are happy to be able to join this endeavor as a group and establish new thoughts. We think the assignment is finished as required, and the information gathered during this time will be useful in our future business endeavors. We might also want to mention that the fate of new world locations is home computerization.

8. 2 Future Scop

The next step in the home robotization market will depend on a few significant changes to the automation development process, such as better automation designs and a decrease in the amount of attention given to home automation as the market begins to recognize its use in larger quantities. During this period of the business, we anticipate the following two examples. In the long run, large corporations such as Siemens, Schneider, and Philips will release true mass-market mechanized products that interface with user interfaces at a lower price point than they do now, and more people will be able to afford them.

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