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A Review Paper on Smart Home Automation System

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Abstract: This paper outlines the development of a home automation system that employs the Internet of Things (IoT) and is powered by a Raspberry Pi. Nowadays, it is uncommon to encounter a residence that lacks a home automation system. The aim of this project is to create a system that allows users to manage home appliances using any mobile device. The integration of IoT technology into home automation is particularly fascinating. The Raspberry Pi, which is a small computer comparable in size to a credit card, is compatible with numerous peripherals and offers various communication options, including Ethernet, HDMI, USB, Display Serial Interface, Camera Serial Interface, and Bluetooth, as well as Bluetooth low energy. This functionality permits the simultaneous management of several home appliances. A local server is set up on the Raspberry Pi, allowing users to control home appliances through various mobile devices such as smartphones, laptops, and tablets, facilitated by a user interface designed on a web page.

Keywords: *Embedded Systems, Home Automation, Internet of Things (IoT), Raspberry Pi, Remote Monitoring.*

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I. INTRODUCTION

The Internet of Things (IoT) is a revolutionary idea that gives each gadget a unique IP address so that they can all be identified and accessed online. The Internet has undergone substantial change. Current trends show that the number of connected devices, or "things," is rapidly increasing, giving rise to the Internet of Things. As more individuals switch from manual to automated systems for efficiency and comfort, this development has the potential to drastically alter daily life. Home automation is one well-known IoT use. This entails automating domestic chores using parts like the Raspberry Pi, relays, and the control circuits that go with them. By substituting programmable electronic controls for manual activities, home automation systems seek to lessen the need for human intervention. By providing the ease of remotely controlling home appliances through mobile phone or the Internet, these systems eventually improve comfort, productivity, and general quality of life.

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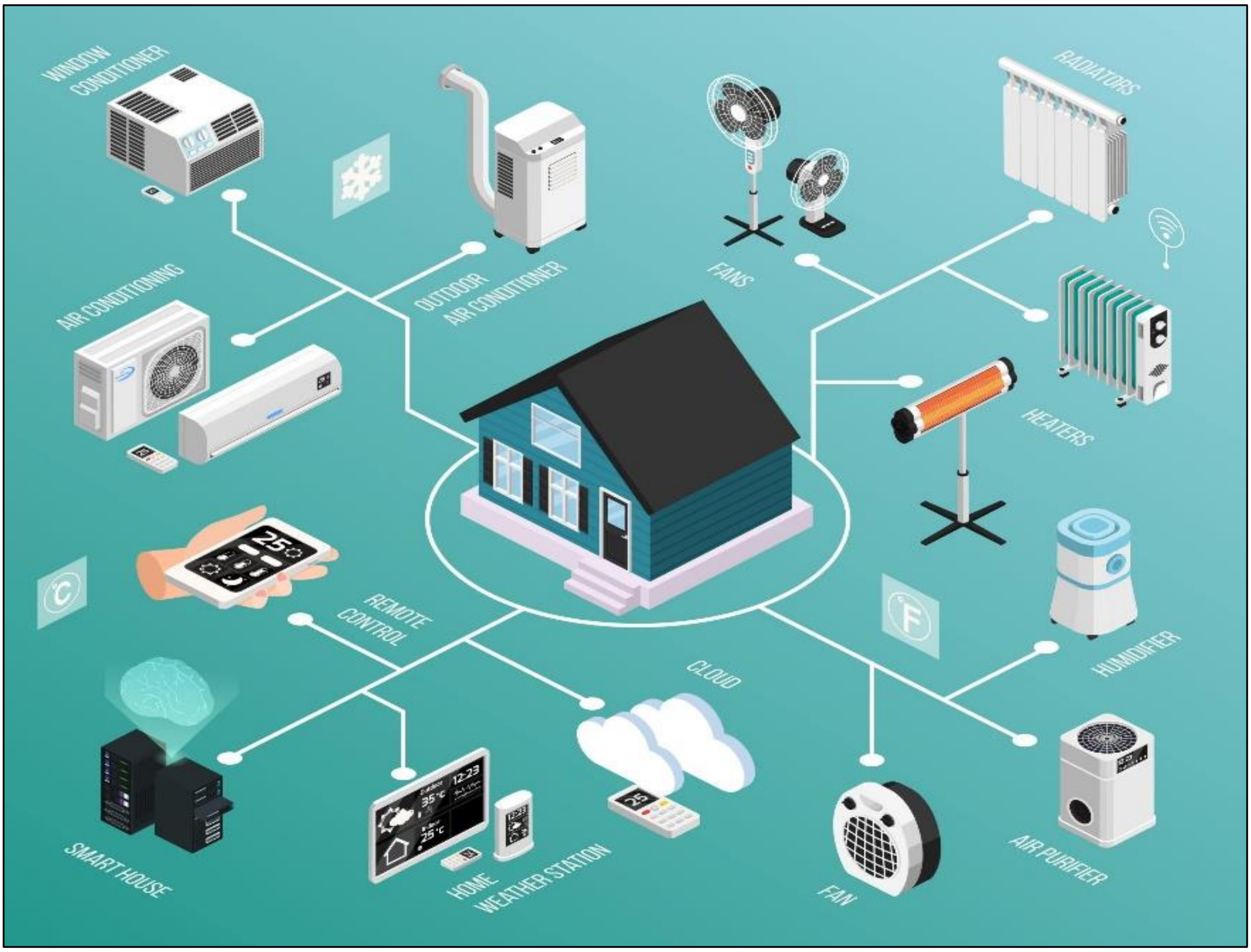

Fig 1 Smart Home

II. LITEARTURE SURVEY

Many experts have pointed out that the Internet of Things (IoT) has the potential to revolutionize many facets of contemporary life, making it a crucial field of study. In order to provide smooth data transmission and real-time decision-making, studies highlight the integration of billions of networked devices and sensors using wireless and other communication technologies. The promise of IoT to boost operational efficiency, improve quality of life, and support data-driven applications across domains including healthcare, transportation, smart homes, and industrial automation is what is driving the increased interest from academia, industry, and government. In order to handle the enormous volumes of data produced by these interconnected systems, the literature also emphasizes the significance of strong data analysis methodologies and effective network architecture.

III. HISTORICAL BACKGROUND AND ADVANCEMENTS IN HOME AUTOMATION

The history of home automation dates back to the 19th century, and significant developments have taken place since then. An early attempt to automate household tasks was made in April 1968 with the development of a prototype called the Electronic Computing Home Operator, which was made from surplus electronic components [1]. A major turning point was reached in the 1970s with the advent of the X10 communication protocol, which allowed devices to use radio frequencies to send control orders like "turn ON" and "turn OFF" via existing power lines [2]. Nevertheless, the X10 system has drawbacks, including slowness, unreliability, and interference vulnerability [3]. The capabilities and accessibility of home automation systems have significantly increased with the introduction of the Raspberry Pi, a low-cost, credit card-sized computer with many connection ports, including Ethernet, USB, and HDMI [4]. It is a well-liked platform for creating intelligent and connected home environments because of its adaptability and simplicity of integration. A comprehensive system, home automation includes many of the features often seen in building automation. It involves managing and keeping an eye on things like doors, windows, HVAC (heating, ventilation, and air conditioning), lighting, security, multimedia entertainment systems, and even more specialized duties like watering plants and feeding pets [5]. Often called "smart homes" or "intelligent homes," the idea of home automation involves network-connected devices that communicate with one another to carry out automatic

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operations according to preset conditions or human preferences [6].

These systems are based on a variety of wireless communication technologies. For instance, the Global System for Mobile Communications (GSM) is particularly helpful in places with poor internet connection since it enables users to operate appliances with SMS commands [7]. Although Wi-Fi might be power-intensive, it offers high-speed data transfer, making it possible to integrate with smartphones and cloud-based services seamlessly [8]. Regarding range, data rate, power consumption, and scalability, each technology has pros and downsides of its own. The automation system's particular needs will determine which protocol is best.

IV. ARCHITECTURE OF THE PROPOSED SYSTEM

➢ *Raspberry Pi*

The Raspberry Pi Foundation, a non-profit organization based in the UK, created the Raspberry Pi line of inexpensive, small single-board computers (SBCs). The Raspberry Pi was first introduced with the primary goal of improving the teaching of basic computer science in schools and underdeveloped nations. Since then, it has become widely used in a variety of fields, including education, hobby electronics, automation, prototyping, and even industrial applications.

A Broadcom System-on-Chip (SoC) that integrates a processor, graphics processing unit (GPU), and multiple I/O controllers forms the foundation of every Raspberry Pi board. The CPU is built on top of the ARM architecture, which is widely used in embedded and mobile systems and is well known for its energy efficiency. Early models had processor speeds of 700 MHz, whereas the Raspberry Pi 4 and 5 had speeds of over 2.0 GHz. RAM capacity has changed as well; more recent models now have up to 8 GB of LPDDR4 memory.

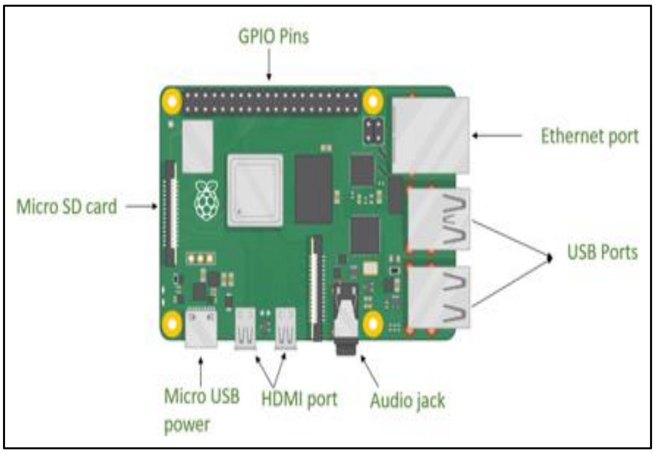

Fig 2 Configuration of Raspberry Pi

➢ *Among the Hardware Features are:*

- **GPIO Pins:** Sensors, actuators, and other peripherals can be interfaced with up to 40 General-Purpose input/Output pins.
- **USB Ports:** To connect devices like keyboards, mice, and storage, there are usually two to four USB ports.
- TVs and monitors can be connected for display using the HDMI output.
- **Camera and Display Interfaces:** Touch screens and camera modules are supported by CSI and DSI connectors.
- **Networking:** For wireless communication, models may have Ethernet connectors as well as integrated Wi-Fi and Bluetooth.
- **Storage:** The operating system and user data are stored on MicroSD cards, which are the main storage medium.

➢ *Relay and Relay Driver Circuit*

An electromechanical switch known as a relay is used to regulate a high-voltage or high-power circuit using a signal with low power. Since microcontrollers (like the Raspberry Pi and Arduino) are unable to provide the current or voltage required to directly operate a relay coil, a relay driver circuit is usually needed in embedded systems and home automation applications to interface microcontrollers with relays. The primary parts of a relay are as follows: A control voltage activates an electromagnetic coil, which produces a magnetic field. When the coil is activated, a mechanical lever known as the armature (switching mechanism) moves. Contacts that are Common (COM), Normally Open (NO), and Normally Closed (NC):

- NO (Normally Open): Until the relay is turned on, the circuit is open.
- NC (Normally Closed): Until the relay is turned on, the circuit is closed.

- *Operation:*

A magnetic field is produced when the coil is subjected to voltage. The contacts change from NO to closed or NC to open as a result of the armature being pulled. A spring restores the armature to its initial position when the coil is de-energized.

A relay driver circuit serves as a conduit between the relay and a low-power control circuit, such as the microcontroller's GPIO. The driving circuit guarantees the safe and proper operation of the relay.

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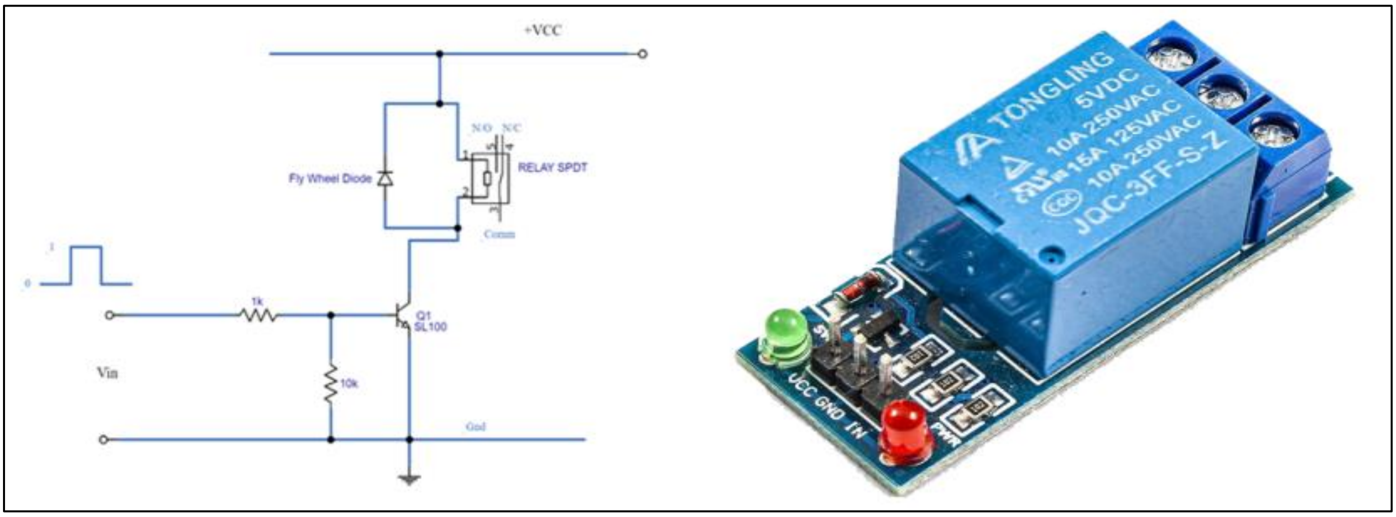

Fig 3 Relay and Relay Driver Circuit

Through the base resistor, the microcontroller sends a HIGH signal to the transistor base. Current can go from the collector to the emitter when the transistor switches on (saturation mode).The switch is activated when current passes through the relay coil. When the coil is turned off, the inductive kickback is safely dissipated by the diode across it, which is reverse-biased during regular operation.

➢ *Mobile Devices*

In order to give consumers access to digital content, communication tools, and computing capabilities while they are on the go, mobile devices are portable, handheld computers. These gadgets, which are essential to the technological architecture of contemporary society, have completely changed how people communicate, interact with information, and carry out daily chores.

The term "mobile devices" describes small, wireless electronics that don't require a constant power source connection to function. Typically, they have a processor, wireless connection capabilities, a rechargeable battery, and a display screen. Typical instances consist of: Smartphones, Tablets, Smart-watches, Personal Digital Assistants (PDAs) etc.

V. OPERATIONAL FRAMEWORK

➢ *Physical Implementation*

A thorough block diagram that acts as the implementation's basic reference was created to make the system hardware design process easier. As shown in Figure 5, the system architecture is conceptually separated into two primary sections: the client (user) side and the server side. A Raspberry Pi serves as the primary control unit and hosts the entire server-side infrastructure. The LAMP stack, which consists of Linux, Apache, MySQL, and PHP, has been set up on the Raspberry Pi to provide reliable web server capabilities and database administration. Two unique PHP scripts were developed and implemented in this setting. These scripts are in charge of responding to client queries, communicating with the database, and sending commands to the Raspberry Pi's hardware. A key component of the Raspberry Pi is its 40 General Purpose Input/output (GPIO) pins, which enable direct hardware interface. The linked household appliances are managed and controlled by these GPIO pins. Relays and other electromechanical devices, which normally require at least 6 volts to operate successfully, cannot be directly activated by the GPIO outputs because they only operate at a logic level of 3.3 volts.

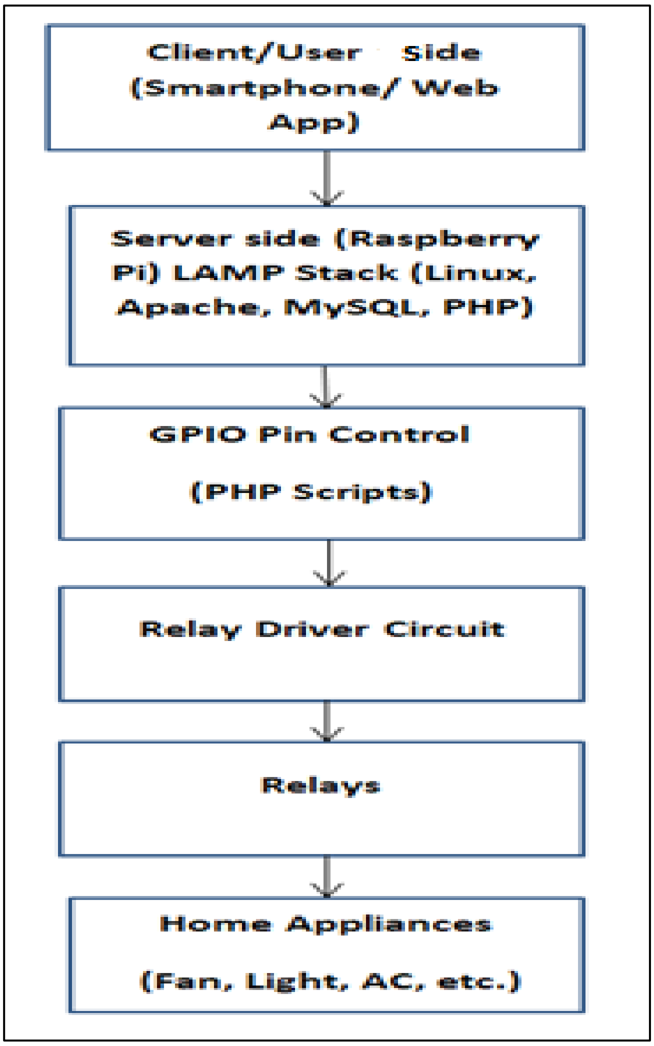

Fig 4 Block Diagram of Proposed Methodology

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A relay driver circuit is added between the relay modules and the GPIO pins to close this voltage and current gap. The Raspberry Pi's control signal is amplified by the relay driver circuit, which supplies enough voltage and current to energize the relay coils. Relays work as switches to regulate the power supply to different household appliances once they are turned on.

The relay modules' output terminals are attached to every electrical appliance in the house that is meant to be automated. This setup allows the Raspberry Pi to remotely control each appliance by turning on or off the associated relays by adjusting the GPIO pins.

- *An Explanation of Flow*

- **Client Side:** Using a smartphone or web interface, the user issues control commands (e.g., turning ON/OFF a light).
- **Server Side:** The Raspberry Pi uses PHP scripts hosted on its LAMP server to send the request over the internet.
- **GPIO Control:** PHP scripts can send signals by gaining access to particular GPIO pins. The 3.3V GPIO signal is converted by the relay driver circuit to a higher voltage and current that can be used to operate relays.
- **Relay modules:** Control the electrical supply to appliances by acting as switches.
- **Home appliances:** Depending on the relay condition, turn them on or off.

The user interface and interaction element of the system that enables end users to remotely monitor and operate household appliances is referred to as the client side. The main component of this side is an interface that consumers may utilize on their phones or computers to transmit commands to the Raspberry Pi server.

The Raspberry Pi is connected to the client device via the internet or Wi-Fi. Usually, communication is accomplished by: PHP programs running on the Raspberry Pi receive HTTP requests (GET or POST) from the client. If the server is outside of the local network, it can be accessed via the Raspberry Pi's public IP/DNS or local IP address. A feedback loop can be incorporated into the system to enhance the user experience: Every GPIO pin or relay's condition is read and shown on the client interface. The user is informed of the appliances' present status using status indicators, such as ON/OFF labels and colourful LEDs in the user interface. Web-Socket connectivity for real-time updates or AJAX polling can be used to implement this feedback.

- *Execution of Software*

In order to facilitate communication between the user and the smart home gadgets, the software is essential to this work. The complete system is programmed using PHP and is operated on a Raspberry Pi configured as a local server using the LAMP (Linux, Apache, MySQL, PHP) stack. The usage and implementation of the software in this smart home automation system are described below. PHP files are hosted on a Raspberry Pi that is set up with the LAMP server. The Apache server's /var/www/html directory contains the required PHP scripts, switchDevice.php and index.php. Any device connected to the same network can access the web interface by virtue of the Raspberry Pi's local network connection. By entering the Raspberry Pi's IP address in a web browser, users can access the smart home control panel (e.g., http://192.168.1.xxx/index.php).

A user-friendly interface with buttons or toggles to control smart appliances, fans, or lights is displayed by the index.php file. Every control on the user's screen has access to switchDevice.php's backend routines, which handle user commands.

SwitchDevice.php receives a request from the index.php file when a user hits a button (for example, to turn on a light). The request for information is processed by the switchDevice.php script, which then signals the linked device (such a relay module) to activate a GPIO pin. The corresponding equipment is either activated or deactivated by the signal. According to the actions that have been carried out, the web interface modifies individual device's present condition (ON/OFF). Customers can observe the impact of their interactions in real time attributable to this feedback chain. Any PC, tablet, or smartphone connected to the same Wi-Fi network can access the system for local control. Remote access can be safely enabled with further settings (such as port forwarding or dynamic DNS). In order to add new devices or alter the interface layout, users can alter the PHP codes. A MySQL database can be enhanced with logs and status information to track utilization or energy conservation.

VI. SIMULATION & RESULT

Hardware and software components were used to simulate the smart home automation system. The goal of the simulation was to simulate using an Internet of Things-based platform to control and monitor household gadgets in real-time. Having a Raspberry Pi set up as an in-house server operating the LAMP stack, the designed home automation system was put into practice. Dependability, adaptive design, delays, and compliance with a range of mobile platforms, notably Android laptops, tablets, and smartphones, were all extensively evaluated.

- *The Subsequent Essential Features were well Displayed:*

- Device Control: Using a web-based interface that was accessible through a local IP address (e.g., http://192.168.1.xxx/index.php), users were able to turn on and off a variety of household appliances, including lights, fans, and outlets.
- Real-Time Feedback: The web interface of the system displayed real-time status updates. Almost immediately after a relay was activated, the web interface showed the updated state (ON/OFF).
- GPIO Functionality: By effectively transmitting control signals through the relay driver circuits, the Raspberry Pi's GPIO pins were able to power the relays and switch the linked electrical appliances as needed.

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- Relay Circuitry Reliability: The Raspberry Pi's 3.3V logic signal was boosted by the relay driver circuit to the necessary voltage and current level in order to run the relays consistently across several test cycles.
- Web Interface Responsiveness: All tested devices and browsers (Chrome, Firefox, and Safari) experienced fast loading times. With less than a second separating the command and execution, button presses were recorded quickly.

VII. CONCLUSION

This IoT-based home automation project's ultimate conclusion represents a major advancement in the incorporation of contemporary technology into daily living spaces. A reliable, user-friendly, and economical solution has been created by utilizing the Internet of Things' (IoT) capabilities and the flexible Raspberry Pi platform. Through internet connectivity, this system makes it possible to remotely control and automate household appliances, converting conventional homes into smart homes. The project's scalability and dependability are among its major accomplishments. The system can be readily extended or modified to include more devices or capabilities without requiring major changes thanks to the modular architecture. A wide range of users, even those with little technical knowledge, can utilize this solution because it uses easily accessible features and freely available resources, which also lowers implementation costs. Functionally, the technology greatly improves home management's energy efficiency, ease, and security. Using a user interface that can be accessed from computers or smartphones, users may remotely control lights, fans, and other appliances from anywhere in the world. This degree of control enables customers to monitor and control their gadgets in real-time, which not only enhances comfort but also promotes more intelligent energy consumption. The research concludes by showing how the Internet of Things has the potential to change how we interact with our living areas. It opens the door for additional study and advancement in smart home technology, fostering creativity in the direction of automation solutions that are more effective and user-focused.

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