Smartify :Transforming Traditional Appliances into Smart Devices For Seamless Home Automation

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**Abstract**

In the realm of home automation, efficient control systems are pivotal for seamless user experience. This paper presents a novel approach utilizing Internet of Things (IoT) technology, specifically employing the ESP8266 and ESP32 microcontrollers, to develop a smart home automation system. Leveraging Firebase Realtime Database (RTDB) for data storage and retrieval, coupled with Infrared (IR) remote control functionality, this system enables remote monitoring and control of household appliances. The system architecture integrates WiFi connectivity for seamless communication between the microcontroller and the Firebase RTDB, ensuring real-time synchronization of device states. Additionally, IR remote functionality enhances user interaction by allowing direct control of appliances. The implementation encompasses robust error handling mechanisms to ensure reliability and consistency in data transmission. Key features include dynamic relay state management, achieved through IR remote commands or physical switches, and seamless integration with Firebase for persistent storage and retrieval of device states. Moreover, the system incorporates token-based authentication for secure access, enhancing privacy and data integrity. Experimental results demonstrate the efficacy of the proposed system in providing reliable, real-time control of household appliances, thereby showcasing its potential for enhancing user convenience and energy efficiency in smart home environments

***Keywords: Home Automation,WI-FI Control, ESP32,Mobile app,Retrofitting, Internet Of Things(IOT),IR remote***

## 1.Introduction

In today's dynamic world where technology continually reshapes our daily routines, our Smart Home Automation Project stands as a beacon of innovation, seamlessly blending cutting-edge IoT advancements. Smartify revolutionizes traditional appliances by imbuing them with smart capabilities, thus contributing to the overarching goal of home automation. Through the integration of IoT technology, Firebase Realtime Database synchronization, and Arduino microcontroller adaptability, we enable traditional appliances to seamlessly communicate, adapt, and respond to user

commands and preferences.

Firstly, our project equips traditional appliances with IoT connectivity, allowing them to communicate with other devices and the central control hub. By integrating sensors and Wi-Fi modules, we enable appliances to transmit data and receive commands, transforming them into nodes within a cohesive network of smart devices.

Secondly, Firebase Realtime Database serves as the backbone of our system, facilitating seamless communication and synchronization among all connected appliances. This ensures that device states are updated in real-time across the entire system, regardless of the control mechanism used. As a result, traditional appliances become part of a dynamic ecosystem where they can interact and coordinate with other devices to optimize performance and enhance user experience.

Furthermore, Arduino microcontrollers provide the versatility and flexibility needed to retrofit traditional appliances with smart functionalities. By interfacing with sensors, actuators, and communication modules, Arduino boards enable appliances to perform a wide range of tasks, from monitoring environmental conditions to adjusting settings based on user preferences.

Overall, our project transforms traditional appliances into smart appliances by enhancing their connectivity, intelligence, and interoperability. By seamlessly integrating them into a unified system of home automation, we empower users to enjoy greater convenience, efficiency, and control over their living environment, ushering in a new era of intelligent living.

## 2. Literature Review

Many researchers have proposed various solutions in smart home areas such as home automation, safety, security, and energy consumption for human life facilitation. Some of these solutions are discussed in the following.

**2.1 Home Automation, Saftey and security**

There are many approaches available for home automation, safety, and security to enhance the lifestyle of human beings. The automation part controls home appliances, such as lights, fans, and ACs [16]. Several researchers deployed a microcontroller-based

home automation system in which a microcontroller is used as a server, and an Androidapplication is used to access the system through the Internet. Usually, the Arduino board is used as a server, which is a low-cost microcontroller, and is a part of the computer, and

can run only one program at a time [17,18]. This approach is further extended by [27] by integrating temperature and current (voltage and ampere) sensors with a home automation system. A wireless home automation system built on Arduino is presented in [14].

It provides two modes. A manually operated mode to control home appliances through a smartphone and a self-automated mode to automatically control home appliances throughconnected sensors. The hardware implementation with Matlab-GUI made the system expensive (need a PC) and required more power to run the system. A system to control and

tor home appliances, using the WLAN network based on the Arduino is presented in [28], but HTML5 supportable devices can only access this system. It also requires a PC server to run the system making it less cost-effective. A hybrid home automation system is developed in [29] in which X10 wired, and ZigBee wireless technology is used.

The approach followed smart task scheduling with a heuristic for the RCPSP (resourceconstrained scheduling problem). The author in [30] developed a home automation system to control and monitor home appliances through the home getaway, which is based on ZigBee, Android application, and Arduino.

Some researchers have proposed Bluetooth enabled home automation system. For instance, in [31], the authors developed a home automation system that includes a primary controller and Bluetooth sub-controller connected to a single home device. Another Bluetooth-based home automation system which uses cell phone was presented in [2], in which home appliances are connected to the Arduino board. The cell phone and Arduino are connected through Bluetooth technology. A security filter has been used in this approach to secure the system from unauthorized access. The main disadvantage of a Bluetooth-based home automation system is that it can only be accessed in an indoor environment or within the Bluetooth range.

A voice control home automation system has been presented in [32], which comprises two main parts, i.e., voice recognition system, and wireless system. The Android application was used for voice recognition and Bluetooth technology for connecting different modules wirelessly. In this system, the authors used three different technologies such as Bluetooth, Wi-Fi, and ZigBee. Using multiple communication devices requiring separate protocols for communicating with each component makes the system unfeasible and increases the implementation cost. Another voice-based automation system has been developed in [33], but the Open Platform Communications server makes the system costly.

A Zigbee-based home automation system is proposed in [13], including home network devices and home network gateway to operate home appliances. Besides home automation, the safety and security is another key feature of a smart home, where several researchers proved their contribution. A home automation and home security system based on ZigBee is presented in [34], providing multi-home communication capability. However, the user controls home appliances by sending a command through SMS to the main controller. A home safety and security system is proposed in [15],in which an elderly fall and flame and gas detection mechanisms are used to protect the elderly population from any kind of hazard. The security

aspect for smart homes based on the passive infrared sensor (PIR) and Arduino is proposed in [35]. In this research work, the authors used a PIR with Arduino for motion detection, and camera sensors are used with PIR for intruder detection. When the PIR sensor detects a motion, the camera sensors will be activated to capture an image. Furthermore, they used a histogram of gradient (HoG) to extract prominent features from the captured image, and these features are fed to the support vector machine (SVM) for intruder detection. If the intruder is detected, the system turns on the alarm to warn the homeowner about the activity.

The experimental results demonstrated that it only takes two seconds for detecting motion,and their approach reached an accuracy of 89% for intruder detection. The system had ahigh misclassification rate and often triggered an alarm for normal activity. There is still room to improve the accuracy in this case by using modern mechanisms. In [36], the authors incorporate fog computing technology to analyze foot size, pressure, and movement in real time for person identification. A predictive learning-based Adaptive Neuro-Fuzzy Inference System (ANFIS) is used for intruder detection. Furthermore, in this approach, they raised an alarm in the case of any emergency in real-time situations. Their work is validated in a smart home environment database selected from an online repository called the UCI, which comprises 49,695 records. It consists of Identity-based parameters, foot size, pressure, namely weight, and movement. Superior performance is achieved by their proposed work as compared to other SoTA prediction models. Jan et al., [15] proposed a technique for detecting a person falling on the floor, flames, and leakage of any harmful gas detection. This system is aimed for elderly persons and uses an RPI-based prototype that can be easily mounted to the elder people as a safety device. In the case of any emergency, the system is responsible for sending an alarm message to their relatives along with their global position system (GPS) location.

**2.2 Home Energy Consumption:**

Besides automation, safety, and security, another important aspect of the smart home is the reduction of energy costs. For residential usage, energy consumption is increasing day by day. For this purpose, a different module of a smart home has been implemented, such as controlling home lights automatically considering natural light. Numerous research works proposed that daylight can be substituted for limiting electricity consumption in commercial buildings automatically via light sensors. Therefore, there are many approaches available to decrease residential energy usage [37,38]. Smart home technologies include ICT, sensors, and network capability to automatically switch home appliances through a smartphone application, touch screen, or voice [39]. Smart meters and instruments provide better prospects for the user to efficiently manage and control their home electricity [40]. Han et al., in [41], presented a ZigBee-based energy management technique that measures the usage of energy by home appliances (electrical, electronic devices). They also used a power line communication (PLC)- based approach for the measurement of energy generation. For smart homes, Anvari et al. [42] developed a multi-objective mixed integer nonlinear programming model for optimal energy use. The result showed that the algorithm not only reduced utility bills and domestic energy usage but also provided optimal task scheduling and a thermal comfort zone for the residents. In [43], the researchers provided an efficient mechanism to control the energy consumption of two different climate regimes such as Algiers and Stuttgart, cities in Algeria and Germany. The solution was aimed at a single-family house, but it was not cost-effective due to the implementation cost.

**2.3 IOT Platforms for Smart Homes**

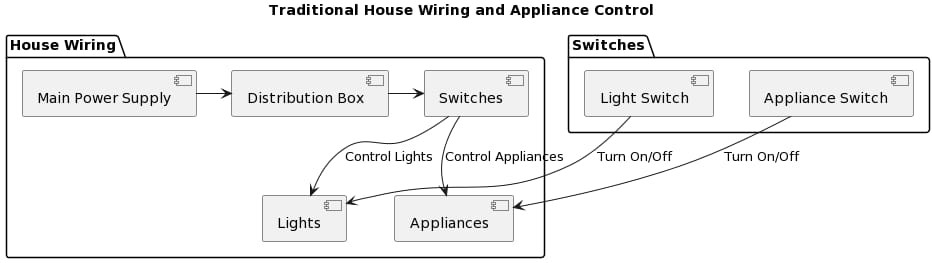
The network is an important part of smart objects connectivity. Smart objects include controllers, sensors, actuators, and different processors, which are used to control, monitor, and communicate with each other in the network [20]. Smart home takes advantage of cloud computing [44], but there are significant deficiencies in cloud computing including latency and response time. For this purpose, Li et al. proposed a technique in [45] to overcome cloud computing limitations. They studied the problem of data latency and response time of the smart object (used in smart homes and smart cities) in cloud computing and decided to switch from cloud to fog computing, which enabled the real-time interaction of the smart object, overcoming latency and data volume and speed issues. Scalability is another issue in cloud computing as discussed by Faruque et al. [46]. Fog computing provides a better energy management strategy. Adaptability, Scalability, and open-source hardware/software included in the fog computing paradigm facilitate the user to reduce the implementation cost, time, and energy consumption with customized control-as-service.

Perera et al. [47] studied resource wastage issues in cloud computing and network storage. However, a new fog computing paradigm that has limited computational capabilities at the edge cannot address this challenge alone. To address this challenge, both paradigms need to collectively build supportable IoT infrastructure for smart cities. Fog computing faces new privacy and security issues. In the perspective of fog computing, Yi et al. [48] discussed several security issues including data storage security, computation security, and security of the network, and highlighted some other issues regarding data privacy, user privacy, and privacy of the location. Most fog computing applications in IoT only collect data from homogeneous IoT devices but cannot collect data from hybrid IoT devices into one real IoT application. Lu et al. [49] introduced a lightweight privacy-preserving aggregation scheme of data for fog computing to enhance the usage of fog computing in IoT applications. The lightweight privacy- preserving data aggregation (LPDA) employs different privacy techniques, Chinese remainder theorem, homomorphic Paillier encryption, and one-way hash chain technique. Amadeo et al.

[50] conducted a study where they highlighted the benefits of fog computing over cloud computing. They rely on Information-Centric Networking to control and monitor the smart home environment and presented a reference architecture as proof of concept.

Edge computing has recently gained a lot of attention in which the data are processed over the edge overcoming dependency, latency, security, and data privacy issues. It is an ideal paradigm for designing efficient home solutions comprising various IoT devices. Our proposed system takes advantage of this paradigm. It has shown to significantly improve the response time and the latency issues operating multiple home appliances.

**3. Existing System:**



In many households, conventional appliances lacking smart capabilities and Wi-Fi connectivity remain prevalent, presenting both advantages and disadvantages. While these appliances may offer reliability and familiarity, they are limited in their integration into modern smart home ecosystems. The absence of Wi-Fi connectivity prevents seamless remote control and management, leading to inefficiencies in household operations. Traditional methods of upgrading to smart appliances often entail high replacement costs, rendering them inaccessible to users with budget constraints or those reluctant to replace functional appliances.

**3.1 Advantages**

1. **Reliability:** Conventional appliances are often perceived as reliable and durable, with proven performance over time.
2. **Familiarity:** Users are accustomed to the operation and maintenance of conventional appliances, reducing the learning curve associated with new technologies.
3. **Cost:** The initial cost of conventional appliances is typically lower than that of smart alternatives, making them more accessible to budget-conscious consumers.

**3.2 Disadvantages**

1. **Limited Integration:** Without Wi-Fi connectivity, conventional appliances cannot be seamlessly integrated into smart home ecosystems, hindering automation and remote control capabilities.

**2.Lack of Remote Control:** Users are unable to remotely control and manage non-smart appliances, resulting in limited convenience and efficiency in household operations.

**3. High Replacement Costs:** Upgrading to smart appliances involves expensive replacements, which may not be feasible for all users, especially those with budget constraints or functional non-smart appliances.

**3.3 Potential Gaps and Limitations of Existing System:**

1. **Technology Obsolescence:** Rapid advancements in smart home technology may render current devices obsolete, leading to compatibility issues and the need for frequent upgrades.
2. **Interoperability Challenges:** Integrating devices from different manufacturers can be challenging due to compatibility issues and disparate communication protocols.
3. **Financial Constraint**s: The high cost of replacing conventional appliances with smart alternatives may deter users from adopting smart home solutions.
4. **User Experience Limitations:** Complicated setup processes, unreliable connectivity, and inconsistent performance can detract from the user experience and hinder widespread adoption.

Despite these limitations, there is potential for innovative solutions to bridge the gap between conventional appliances and modern smart home ecosystems. By addressing the challenges of technology obsolescence, interoperability, cost, and user experience, the Smartify project aims to empower users to transform their existing appliances into smart devices, enhancing convenience, efficiency, and connectivity in the home environment. Through seamless integration and intuitive user interfaces, Smartify seeks to overcome the limitations of existing systems and deliver a comprehensive smart home solution for users of all backgrounds and preferences.

**4. Proposed System:**

Smartify presents a comprehensive solution tailored to elevate conventional household appliances to smart devices, catering to the escalating need for advanced home automation while circumventing the constraints of non-Wi-Fi enabled devices. The proposed system harnesses the functionality of smart plugs and switches, enabling remote control of power supply to a myriad of appliances, including air conditioners, televisions, and more. By integrating Wi-Fi connectivity and interfacing with a dedicated mobile application, Smartify empowers users to effortlessly monitor and manage their appliances from any location, at any time. Additionally, the incorporation of an infrared (IR) remote control feature enhances user convenience, allowing direct control of appliances via remote commands. This comprehensive approach ensures seamless integration of smart functionality into existing household appliances, offering users unparalleled convenience, flexibility, and control over their home environment.

**4.1 Module Design:**

1. **Connection Establishment Module:**
   * Responsible for establishing a connection to the local Wi-Fi network.
   * Enables the device to communicate with the Firebase database over the internet.
   * Ensures that the device has internet access for data exchange.

## Authentication and Streaming Module:

* + Manages communication with the Firebase Realtime Database (RTDB).
  + Handles authentication with the Firebase server using API keys and authentication tokens.
  + Facilitates reading, writing, and updating data in the Firebase RTDB.
  + Utilizes stream callbacks to receive real-time updates from the database.

## Authentication and Authorization Token Generation and Management Module:

* + Assists in the generation and management of authentication tokens required for Firebase authentication.
  + Ensures secure authentication and authorization of the device with the Firebase server.

## RTDB Helper Module:

* + Provides helper functions for handling Realtime Database (RTDB) operations effectively.
  + Helps in parsing and processing RTDB payloads received from the Firebase server**.**
  + Manages stream callbacks to handle real-time data updates from the database.

## GPIO Module:

* + Controls the General Purpose Input/Output (GPIO) pins of the microcontroller.
  + Manages the interface with relay and switch components connected to the GPIO pins.
  + Allows the microcontroller to toggle the state of relays based on commands received from the Firebase RTDB.
  + Ensures secure authentication and authorization of the device with the Firebase server.

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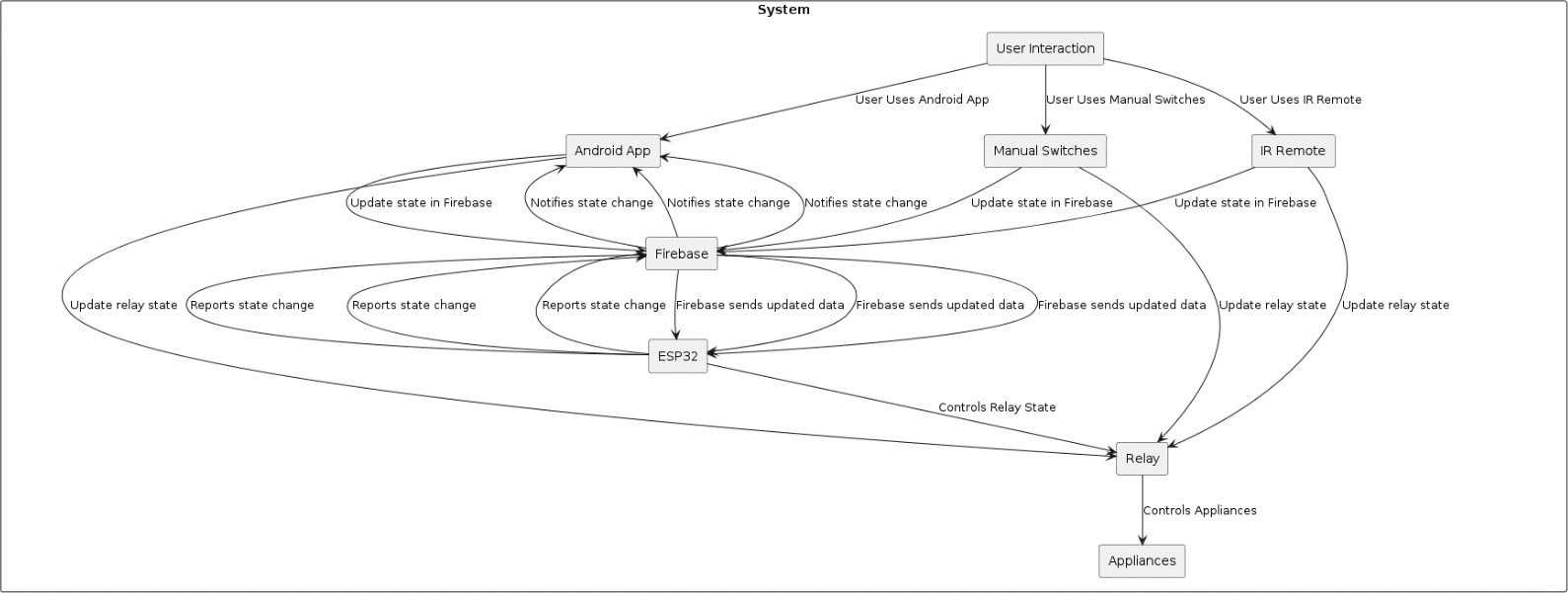
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## 4.2 Advantages:

* Cost-Effective
* Seamless Integration
* Remote control and Monitoring
* Intuitive User Interface

5. Smart Infrastructure:

**6. Conclusion:**

Home automation offers numerous benefits, from convenience and energy efficiency to improved security and peace of mind. By integrating smart devices and systems into your home, you can automate various tasks, such as adjusting lighting, controlling temperature, managing appliances from your smart phone. This not only enhances comfort but also allows for more efficient use of resources and potentially lowers utility bills.

Additionally, home automation systems often provide data insights that enable users to make informed decisions about their energy consumption and overall household management. By analyzing usage patterns, homeowners can identify areas where they can further optimize their energy usage, leading to potential cost savings and reduced environmental impact

As technology continues to advance, the possibilities for home automation are virtually limitless. From intelligent appliances to fully integrated smart home ecosystems, the future of home automation promises even greater convenience, efficiency, and customization. However, it's essential to consider factors such as privacy, security, and interoperability when implementing home automation solutions to ensure a seamless and safe experience. Overall, home automation represents a significant advancement in modern living, offering convenience, efficiency, and peace of mind to homeowners worldwide.

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