

IoT SMART HOME SYSTEM USING ESP32 WIRELESS TECHNOLOGY

Mohammad Harith Irfan Mohd Syukran*, Norzilawati Abdullah

Politeknik Kota Bharu, Kelantan, Malaysia

*Corresponding author: harithirfan1106@gmail.com; norzilawati.ab@gmail.com

Abstract

In this digital era, IoT technology has played an important role in improving life and energy efficiency, especially for residential areas. The project designed a smart home system that could enable users to control home appliances easily and efficiently. This project focuses on the design of a smart home system that enables users with ease and efficiency to control the home appliances. Most of the traditional systems lack ease and flexibility, which the present user aspires to, hence the need for such systems which can allow control and automation remotely to achieve better comfort with energy consumption. The main objective of this project is to design an IoT Smart Home using an ESP32 module-based light and fan control system connected with the Telegram application for user control of lighting and fans using smartphones. This approach is where the system design and development will be carried out with the ESP32 module, sensors, and the Telegram application. Testing processes were conducted to ensure the system functions properly, including connection testing, application responsiveness, and device control efficiency. The results of this project indicate that the developed system operates effectively, enabling users to easily control lights and fans through the Telegram application. This system also demonstrates the potential to enhance energy efficiency and provide convenience to users. Overall, the project successfully achieved its objectives, with a system that operates effectively and responsively, proving the effectiveness of using the ESP32 and Telegram application in developing a practical and innovative smart home system.

Keywords: ESP32, IoT, Smart home system, Telegram application

INTRODUCTION

The growing technological advancements have contributed to the development of the Internet of Things (IoT) and its applications in smart homes, which can help in automating and providing comfort to users. The connectivity of smart devices has gone beyond communication, which presents unique opportunities and capabilities to place smart systems integrated with electrical appliances in the home more efficiently (Chataut *et al.*, 2023; Papageorgas *et al.*, 2023).

Furthermore, construction companies and manufacturers are now specializing in energy-efficient systems that combine various technologies for seamless sensor integration. There are many advantages to such constructions including easier maintenance and flexibility in design, as well as additional security features such as motion sensors. This makes residential homes safer when left unattended (Papageorgas *et al.*, 2023; Junior, 2023).

By harnessing technologies like motion sensors, security cameras, and voice control, individuals can remotely oversee and manage their residences. This offers substantial advantages, particularly in enhancing energy efficiency and instilling a sense of security for homeowners. Additionally, the integration of smart technology with devices such as Amazon Alexa and Google Home facilitates easier and more intuitive control (Weber *et al.*, 2023). This enables numerous devices to communicate wirelessly with superior performance, rendering smart homes more accessible to individuals from diverse backgrounds (Papageorgas *et al.*, 2023).

Thus, this project presents an IoT smart home system using ESP32 microcontroller, which enables the control of different home appliances such as lights and fans. The system consists of three types of sensors, the first is an LDR (Light Dependent Resistor) sensor to determine the ambient light level in the environment. The second is a motion sensor that monitors human presence by detecting movement, while the last is a DHT11 sensor that measures temperature and humidity.

The ESP32 processes these sensor data internally to produce real-time actions such as turning lights on or off depending on the lighting or controlling fan speed based on temperature and humidity conditions. The system is also integrated with a Telegram bot, where one can monitor changes and get notifications where, the user will receive notifications about changes in the status of the environment and devices.

Therefore, this project is able to produce affordable and friendly IoT hardware with events and conveniences in the smart home, featuring a methodology of convergence between IoT and daily life towards improved energy efficiency and convenience.

LITERATURE REVIEW

In recent years, there has been a lot of interest in developing an IOT smart home system using the ESP32. A literature analysis on this subject demonstrates the many ways and approaches offered to increase home security by utilizing these technologies.

Internet Of Things Concept

The Internet of Things (IoT) is a system of networked devices, machines, objects, and living things, each with unique identifiers (UIDs) and the capacity to communicate data autonomously (Khan & Yuce, 2019). By extending computing and network connectivity to commonplace objects, this paradigm allows them to gather and share data on their own. Conceptualizing the connection between machines over the Internet enables communication and data exchange for multiple devices, including smartphones, wearables, and home appliances (Dubey & Yadav, 2024). IoT Devices is also able to link away devices and make it possible for better communication between devices connecting actuators and sensors (Abinayasree, 2024). Therefore, the Internet of Things' ability to integrate digital and physical entities is anticipated to have a big impact on how the Internet develops in the future.

Smart Home System

Smart home systems (SHS) integrate a variety of technology to improve living conditions and provide services suited to inhabitants' requirements (Chakraborty *et al.*, 2023). These systems often combine IoT devices, sensors, and networking technologies to form linked ecosystems (Herlian *et al.*, 2024). Key functionalities include security measures such as infrared sensors and motion detection cameras (Chiu *et al.*, 2020), as well as automatic lighting and climate management (Herlian *et al.*, 2024). Voice recognition and smartphone connection provide more user ease and control (Chiu *et al.*, 2020). Thus, the application of SHS can result in increased energy efficiency and overall quality of life. As these systems grow, technologies have the potential to help create a more sustainable and connected future.

ESP32 Module

Smart home systems have been transformed by the integration of IoT technology and the ESP32 microcontroller, which improves automation, security, and environmental monitoring. The ESP32 is a flexible option for contemporary living because of its capabilities, which enable smooth communication and control of a variety of household appliances. The paper proposed by (S *et al.*, 2024) describes an ESP32-based home automation system that uses Wi-Fi for remote control and environmental monitoring. It combines relay modules with DHT11 sensors to provide seamless automation and improve home comfort, convenience, and energy savings via a user-friendly smartphone app. Moreover, the integration of ESP32 with IoT technologies is highlighted in the papers by (Patil *et al.*, 2024) on a home automation system. It highlights how popular smart home appliances like the Amazon Echo are becoming and how they improve convenience and user control in home automation applications.

The paper written by (Badoni *et al.*, 2024) proposed the ESP32-CAM module enables high-resolution facial recognition for secure access control, reducing unauthorized entry risks. While paper from (Saputra *et al.*, 2024) solves the problem by using ESP32-based IoT solutions where it can identify early warning indicators of gas leaks and fires, notifying users in real-time to help avert catastrophes. Therefore, from the results of the literature review, ESP32 has many advantages when used in smart home systems.

RESEARCH METHOD

The development of this project design consists of the hardware and software systems. This development was done through 3 steps as shown in Figure 1. The first step is to do research from paper journals and case studies, the second step is to develop the project and the third step is testing and implementation.

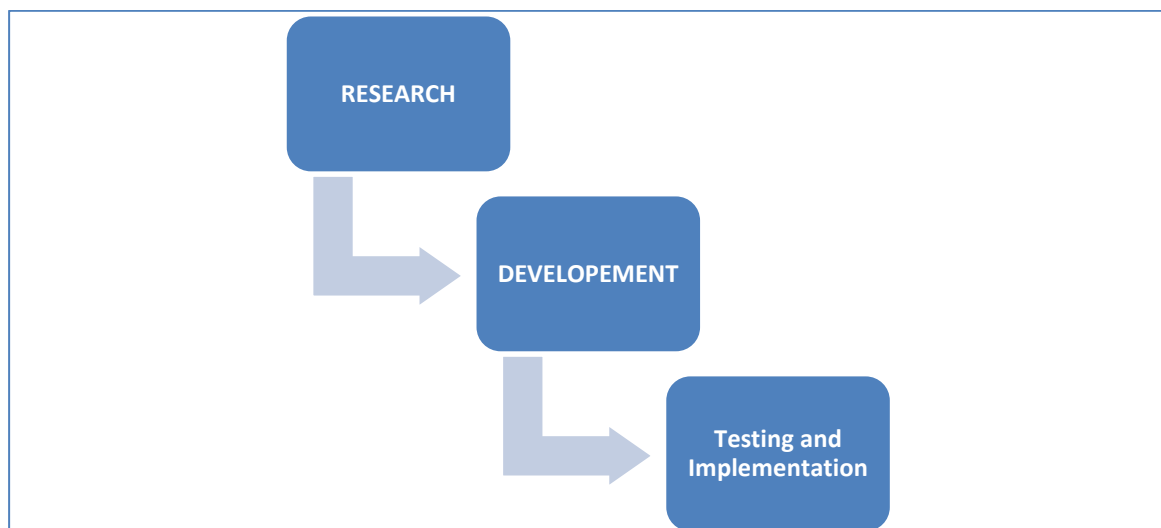


Figure 1: Development phase of the project.

Hardware

The internet makes this entire communication system for this project possible. The Telegram Bot mobile application allows the user to function wirelessly. Together, these make up an IoT-based smart home control and monitoring system that is fully functional and adaptable.

The developed system's block diagram is displayed in Figure 2. The Micro Controller Unit ESP32 module was used, which is at the heart of the system, and regulates the operation of every device that is connected to it. When a command like "ON" or "OFF" is sent and received via Telegram Bot Apps and Wi-Fi, the smart home begins to function. The command will then be sent or received by the Telegram Bot App as a Cloud via a wireless connection to the ESP32 receiver.

The lightbulb, cooling fan, exhaust fan, and LCD with built-in light, temperature, smoke, and motion sensors will then receive an ON/OFF command from the ESP32. The ESP32 will communicate with the Telegram Bot to confirm that the electrical devices are directly connected. An ESP32 board serves as the foundation for the Internet of Things system. Through the use of a WiFi connection, the ESP32 Module is linked to the internet from the smartphone's hotspot.

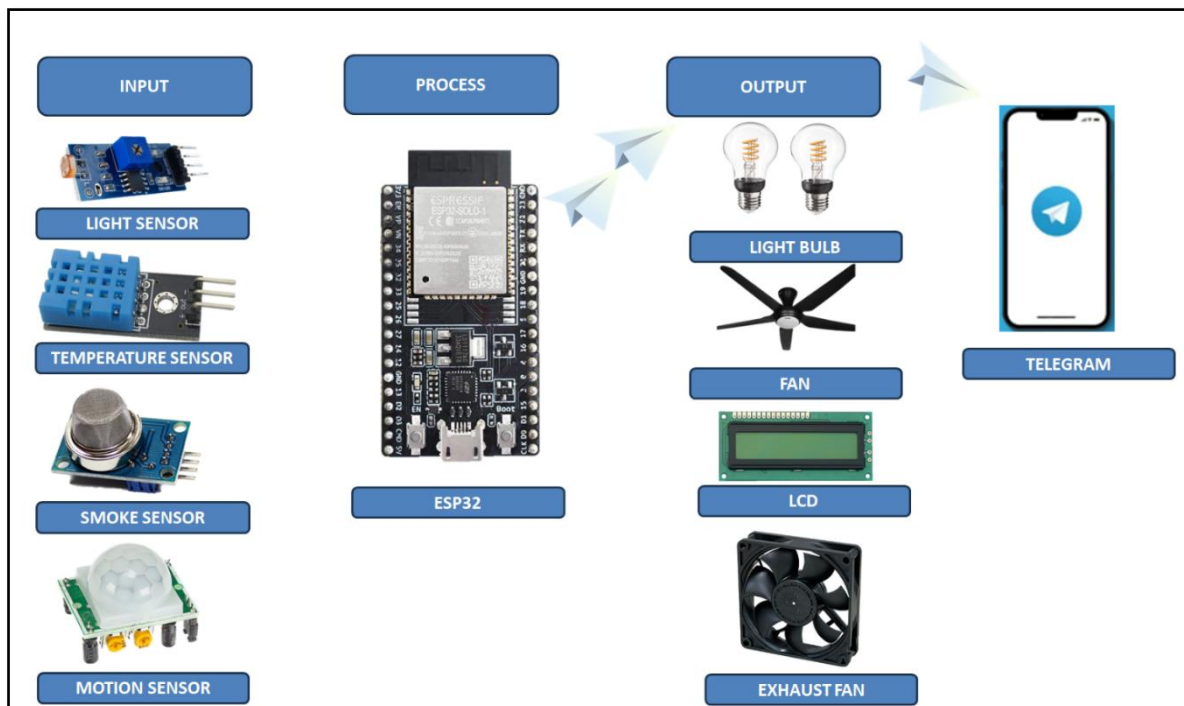


Figure 2: Block diagram of Smart Home System using ESP32 Module.

Software

The Integrated Development Environment software was used to build the "IoT Smart Home System" project using Wi-Fi/Bluetooth by ESP32. An integrated development environment (IDE) that is frequently used for programming ESP32 microcontrollers is the Arduino platform. Inventors can write, modify, and upload ESP32 firmware code using this IDE. The official library that supports software development with the Arduino IDE for ESP32 is the ESP32 Arduino Core Library. The WiFi Library is used to connect the ESP32 to the user's home network via Wi-Fi. - Bluetooth Library: An extra Bluetooth library is needed if the project calls for Bluetooth connectivity.

RESULTS AND DISCUSSION

The project findings process has been carried out on behalf of the IoT Smart Home System Using ESP32 Wifi. Testing between components and ESP32 micro-controllers has been carried out. This process is an important piece of information in evaluating the planned project in terms of its operation, efficiency and effectiveness to enable us to combine or integrate into one system. The process of conducting experiments in this project is a very important aspect of the implementation of the project by emphasizing that through the process all problems that arise can be identified and this facilitates the repair process. The entire system is a combination of the entire circuit and program that is included in the the ESP32 microcontroller.

Testing ESP32 with MQ-2 Sensor

Testing of the MQ-2 Sensor has been carried out. The MQ-2 sensor has 4 pins, namely VCC, GND, Analog Output and Digital output. One pin of the MQ-2 sensor is connected to the ESP32 GPIO and the other two pins to the power supply. The VCC pin will be connected to +5V and the GND pin will be connected to the GND of the circuit. The MQ-2 sensor program uses Digital output. This sensor is an Active Low type, meaning that when there is propane or LPG gas, the gas is detected on the MQ-2 sensor, the buzzer will sound and the exhaust fan will be turned on as shown in Figure 3.

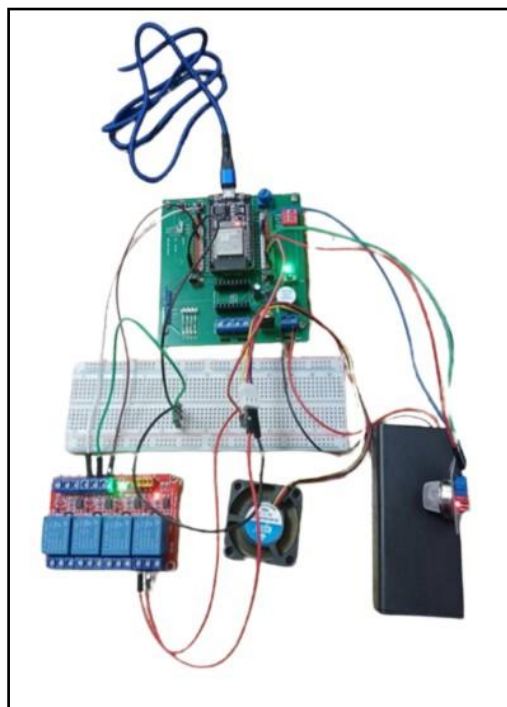


Figure 3: Testing ESP32 With MQ-2 Sensor

Testing ESP32 with PIR Sensor

This sensor is an Active Low type meaning that when this sensor detects the movement of an object, the light will turn on and will be displayed on the LCD showing that there is movement. The PIR sensor has 3 pins, namely VCC, GND, and Output. One PIR sensor pin is connected to the

ESP32 GPIO and the other two pins to the power supply. The VCC pin will be connected to +5V and the GND pin will be connected to the GND circuit. The PIR sensor program uses Output. The results of testing in Figure 4 according to this PIR Sensor show that it has been successfully carried out.

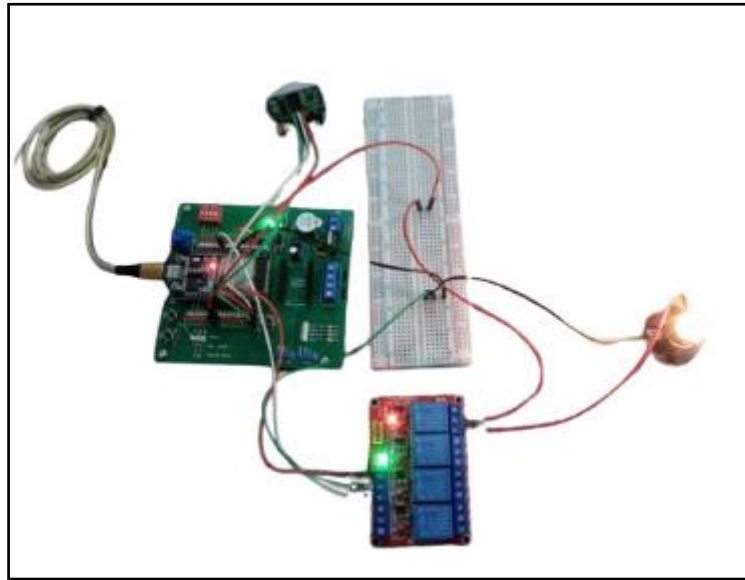


Figure 4: Testing ESP32 with PIR Sensor

Testing ESP32 with LDR Sensor

This sensor is an Active High type, meaning that when this sensor is exposed to light, the light will go out while when the sensor is not exposed to light, the light will turn on. The LDR sensor has 4 pins namely VCC, GND, Analog Output and Digital Output. One pin of the LDR sensor is connected to the ESP32 GPIO and the other two pins to the power supply. The VCC pin will be connected to +5V and the GND pin will be connected to the GND of the circuit. The LDR sensor program uses the Analog output. At the end of the testing process, Figure 5 shows that the testing was successful.

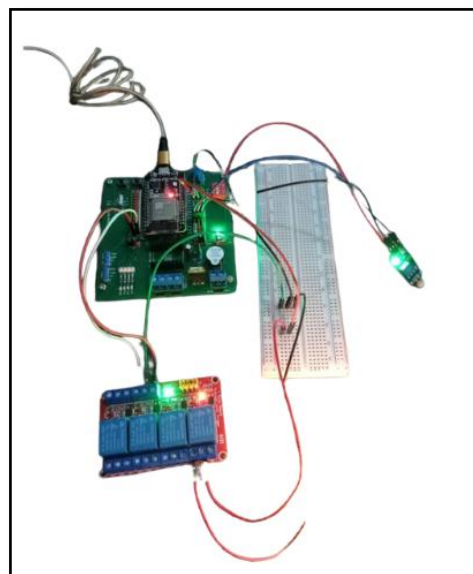


Figure 5: Testing ESP32 with LDR Sensor

Testing ESP32 with DHT11 Temperature Sensor

This sensor is an Active Low type, meaning that when this sensor can measure a set temperature of more than 36 degrees Celsius, the fan will turn on to cool the room in the house. Figure 6 shows the circuit connection. The DHT11 temperature sensor has 3 pins, namely VCC, GND, OUTPUT. One pin of the DHT11 temperature sensor is connected to the ESP32 GPIO and the other two pins to the power supply. The VCC pin will be connected to +5V and the GND pin will be connected to the GND of the circuit. The DHT11 temperature sensor program uses OUTPUT. The temperature sensor test was successful.

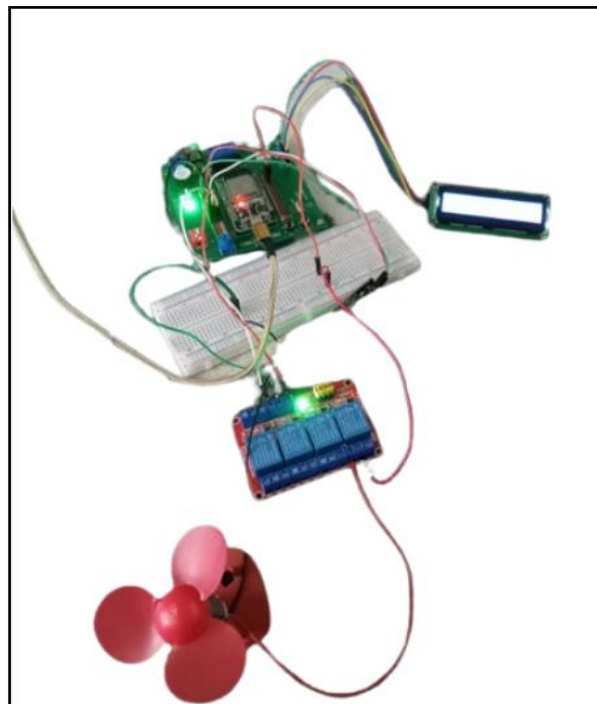


Figure 6: Testing ESP32 with DHT11 Temperature Sensor

Prototype Model

The full model of the IOT Smart Home System using ESP32 WIFI technology prototype, which uses Telegram Bot mobile application indicators to turn on and off the output and monitor, respectively, is displayed in Figure 7 and Figure 8. With the help of an Android OS smartphone and an ESP32 module, the project showcases a flexible and affordable home control and monitoring system that can be operated remotely via the Internet.



Figure 7: Prototype Front View



Figure 8: Prototype with Telegram

CONCLUSION

This project successfully met *all* three main objectives set at the beginning. This shows that the project planning and implementation were done carefully, and the solutions were implemented in accordance with the needs of the users. This system simplifies daily tasks, increases task effectiveness, and reduces users' workload, allowing them to enjoy a more comfortable and organized life.

For future recommendations, this project can be installed with additional sensors for humidity monitoring. By including humidity sensors, the entire home's environmental conditions can be fully monitored, particularly in humid areas. A backup battery system must also be added to this project. This is to guarantee the system's continuous operation during blackouts for users' comfort and safety.

ACKNOWLEDGEMENT

The authors would like to express sincere gratitude to parents and supervisor for giving support and for having contributed greatly to various parts of this project effort. Additionally, the authors would like to welcome the reviewers for their helpful comments and suggestions.

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