

Design and Implementation of IoT-Based Smart Home System with ESP8266 for Energy Efficiency

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ABSTRACT

The development of technology for the Internet of Things (IoT) is increasingly sophisticated, enabling humans to control devices with greater ease. This prototype is designed to contribute to the community, particularly in households, by providing convenience and comfort through home automation. The prototype incorporates several features, including the ability to turn lights on and off via a 5V relay. The doors and garages are equipped with MG90S micro servos, facilitating the opening and closing of these structures. The gate is operated by a DC motor, while the clothesline roof cover is designed to automatically adjust based on the external light conditions, opening and closing in response to changes in brightness. The operation of these systems is managed through the Blink application, which utilizes an Android mobile phone as the control interface

INTRODUCTION

It is undeniable that the development of technological progress is currently growing very rapidly. Such rapid technological advances must be learnt, applied and utilised in everyday life (Adeniyi et al., 2024). One of the technological advances that can be felt is in the field of control. The internet provides various functions and facilities that can be used as a sophisticated information and communication medium. The development of technology that can be utilised from this internet connection is to be able to access electronic equipment, one of which is the control of lights and fans (Adhikari et al., 2024).

The development of technology for internet-based systems is increasingly advanced, helping and making it easier for humans to control a device. The need for a system that can provide comfort is needed by many people. Many ways can be done to meet these needs, one of which is by utilising a smart home system based on the internet of things. Smart home system, which is a computer-aided system that will provide all the comfort, safety, security and energy savings, which takes place automatically and programmed through a computer, in a building or residence (Ananna & Saifuzzaman, 2024). One of the components of a smart home system is a home electronic device control system, because of the large number of electronic equipment ranging from lights, fans, air conditioners, televisions and so on, a control room is needed that can control this electronic equipment so that they can be controlled automatically or remotely (Anjum et al., 2024)

LITERATURE REVIEW

Research by Rachman, 2017 entitled 'Smart Home Based on Iot'. In this study, several devices or home equipment that can be accessed via a computer or bluetooth. Smart home systems on the control and monitoring side still do not support multiple platforms and are still within a limited range, so that in its implementation it is still in short-range communication.

Muhammad Prabowo, 2018 research (2018) entitled 'Designing an Internet of Things-Based Smart Home System'. In this design, the device used is an Iot-based controller, namely nodeMCU with actuators connected are servo motors, relays, and an IR sensor. The method used is the button on the web page and the system will respond to requests from the web page and turn it into an action, namely locking the door or cutting off the electricity.

Research by Rifaldi, 2021 entitled 'Application of the Internet of Things to the Smarthome Prototype Using Voice Patterns with the NodeMCU Microcontroller (Aripin et al., 2024). In thi(Rifaldi, 2021)s study, a voice-based smarthome implementation was carried out in the form of a prototype and application system.

Definition of Smart Home

The term smart home itself means a home equipped with interconnected devices that can be programmed and controlled remotely using a smart phone or computer (Hasan et al., 2020)

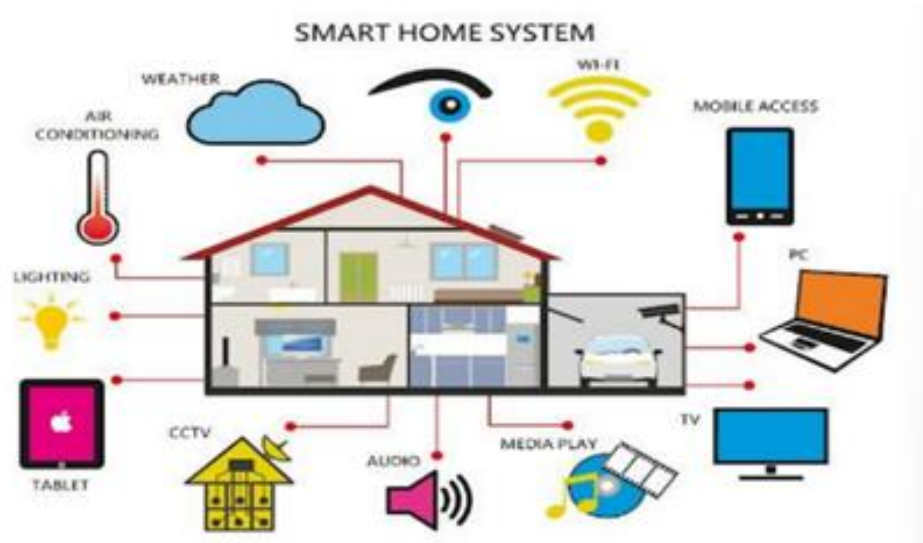


Figure 1. Concept of Smart Home System

Benefits of Smart Home

- 1) Home devices that have a smart home system can provide access to homeowners to monitor home conditions in real time remotely (Humayun et al., 2024).
- 2) Smart home systems can be tied to each other, so that these tools can work together with each other.
- 3) Devices with smart home systems can provide alerts to owners when something happens.
- 4) Smart home devices can generally be customised according to user preferences.
- 5) Smart home devices can be controlled remotely so that users do not need to do anything else.

How Smart Home Works

The way a smart home system works is by linking the main control device such as a smartphone or computer with smart devices in the home such as doors, fans, lights, and so on (Zhu et al., 2024). Later, devices that have been associated with the main control device can be programmed according to user needs. When smart home devices are installed in a home, they can be linked to other systems that belong to the 'Internet of Things' (IoT) devices. Once linked, these devices will be able to share information with each other (Zhong & Nie, 2024).

Internet of Things

Internet of Things (IoT) is a concept that aims to expand the benefits of continuous internet connectivity. Basically, IoT (Internet of Things) refers to objects that can be uniquely identified as virtual representatives in an internet-based structure (Ahsan et al., 2021). In simpler language, the Internet of Things is a network of smart devices that are interconnected and can work automatically

through data exchange (Hussain et al., 2024). The ultimate goal is to create a better experience for users (Bisták, 2019).

Main Components of the Internet of Things

- 1) Smart Devices: These devices are the starting point in the IoT ecosystem, such as CCTV cameras, smart lights, or smartwatches. These devices are usually equipped with sensors that collect data (Ahmad & Saeed, 2021).
- 2) Connectivity Network: This network ensures that IoT devices can connect and exchange data with other devices. Various technologies such as Wi-Fi, Bluetooth, and 5G are used to support this connectivity.
- 3) Cloud Platform: The cloud acts as a storage place for data collected from IoT devices. In addition, the cloud is also a place for data processing and analysis.
- 4) User Interface: IoT devices require a user interface, such as a mobile app or dashboard, that allows users to interact with the device and monitor the collected data (Bagwari et al., 2022).

Components Used

1) NodeMCU V3 ESP8266 Microcontroller

Is a module commonly used for iot projects that are open source. This microcontroller is equipped with a micro USB port that functions to enter the programme to be created and supply power. This microcontroller works at a voltage of 5V and can output a voltage of 3.3V (Guna et al., 2018).

2) Motor DC

An electric motor is an electromagnetic device that converts electrical energy into mechanical energy. DC motor or frequent. called direct current motors. It is more often used for purposes that require speed regulation compared to AC motors.

3) Relay

Relay is an electronic component in the form of an electrically operated switch and consists of 2 main parts, namely Electromagnet (coil) and mechanical (a set of Switch/Switch contacts). This component uses electromagnetic principles to drive the switch so that a small electric current can conduct higher voltage electricity (Log, 2021).

4. LDR Sensor

One of the resistor components with a resistance value that continues to change according to the intensity of light hitting the sensor. So, the more light that hits it, the more the resistance value will decrease. the less light that hits the sensor (dark), the greater the resistance value will be, so that the electric current flowing will be inhibited (Mujiono et al., 2023).

5) MG90S Servo Motor

Is an electromechanical device designed using a control system. Simply put, this servo motor is an independent electrical device that can push, rotate objects with high precision. If you want to rotate an object at a certain angle or distance, you can use a closed-loop type servo motor (servo) as a drive in a circuit that produces torque and speed based on the electric current and voltage available (Candra & Syafrianto, 2022).

6) Power Supply 12V 3A

Simply put, a power supply is a component that supplies power to one or even more electrical loads. So, this power supply is designed to convert several different forms of energy, such as mechanical, chemical, and electrical energy. In computers and other electronic devices, the power supply is an important component. If there is no power supply, the device used cannot function properly (Burian et al., 2019).

7) L298N Motor Driver

L298N Motor Driver is a module that is often used to control DC motors. By using the L298N Motor Driver, we can easily control both the speed and direction of rotation of 2 motors at once (Stirzaker & Driver, 2024). The L298N Motor Driver is designed using the L298 Dual H-Bridge Motor Driver IC containing logic gate gates which are very popular in the world of electronics as motor controllers (Azeta et al., 2019).

8) HC-SR04 Ultrasonic Sensor

LM 2596 Regulator Module is a series of DC/DC converter modules with 150 kHz fixed-voltage fixed frequency (PWM step-down) using the LM2596 Regulator IC, capable of driving 5A loads with high efficiency, low tow and excellent line and load regulation (Software & Ide, 2021).

9) Arduino IDE

Arduino IDE is software used to create programming sketches or in other words, Arduino IDE as a medium for programming on the board that you want to program (Arrahman, 2022). Arduino IDE is useful for editing, creating, uploading to the specified board, and coding certain programmes. The Arduino IDE is made from the JAVA programming language, which is equipped with a C / C ++ (wiring) library, which makes input / output operations easier (Kunal et al., 2020).

10) Blynk

Blynk is a platform for Mobile OS applications (iOS and Android) that aims to control Arduino, Raspberry Pi, ESP8266, WEMOS D1, and similar modules via the Internet. This application is a platform for creativity to create graphical interfaces for projects that will be implemented using only the drag and drop widget method (Sadikin et al., 2019).

METHODOLOGY

This research uses an experimental method with a prototype development approach to design and test a Prototype Smart Home System based on the Internet of Things (IoT). The research process begins with a system design involving main components such as NodeMCU V3 ESP8266 microcontroller, DC motor, relay, MG90S servo motor, 12V 3A power supply, L298N motor driver, and HC-SR04 ultrasonic sensor. The hardware is controlled through programming using the Arduino IDE, while the Blynk platform is used as an interface to monitor and control the system in real-time through an IoT-based application. The design stage includes schematic design, hardware assembly, and microcontroller programming in order to integrate all components optimally (Mukherjee & Dey, 2019).

After the hardware was assembled, system testing was carried out to ensure the functionality and responsiveness of the device in the designed usage scenario. Tests were carried out by testing the connectivity of the NodeMCU V3 ESP8266 to the Wi-Fi network, controlling electrical loads through relays, driving actuators such as DC motors and MG90S servo motors, and measuring distances using HC-SR04 ultrasonic sensors. The test data was collected through the Blynk app, which allows real-time monitoring of the device's condition. Furthermore, the performance of the device was analysed based on response speed, connection stability, and sensor accuracy in detecting objects or environmental changes.

The final step in this research is the evaluation of the system based on predetermined parameters, such as power consumption from the 12V 3A power supply, communication efficiency between the microcontroller and the Blynk application, and actuator reliability in performing the smart home automation function. The evaluation results are analysed to identify potential improvements and enhancements to the system performance. The conclusion of this research will be used to provide recommendations for further development of IoT-based Smart Home System, which is more efficient and adaptive to user needs.

RESULTS

The system workflow depends on internet connectivity that allows devices to connect and exchange data. The following are the working steps of the smart home prototype system:

- 1) **Sensors and Data Collection Devices:** Devices are equipped with sensors that can detect objects, light, or weather. The collected data will be sent to a ESP8266 microcontroller device or the cloud for processing. He chose ESP8266 because this microcontroller already has WiFi in a compact module that will be used as a medium for receiving and sending information or commands from the user's smartphone through the internet network (Internet of Things) with the help of the Blynk IOT application that has been installed and configured on the user's smartphone.

- 2) Connectivity: The collected data will be sent over the internet or a local network using Wi-Fi. This is the reason why connectivity is so important in IoT.
- 3) Data Processing: The data received will be processed both in the cloud and on the device itself to generate a specific response or decision.
- 4) Automatic Action or Response: The result of data processing by the ESP8266 will be passed to actuators such as opening and closing gates, opening and closing garages, opening and closing doors, opening and closing clotheslines, turning lights on and off.

System Implementation Using the Blynk Application

This application is a creative forum to create a graphical interface for projects that will be implemented only by the drag and drop widget method. From this application platform, we can control anything remotely, wherever we are and at any time.

DISCUSSION

Gate Simulation Test Results

After experiments and tests on the IoT-based automatic gate control system, it was obtained that the gate simulation feature has worked according to its function. In this study, the system was developed using the Blynk IoT platform as the user interface, ESP8266 as the main microcontroller, and the DC motor as the actuator that drives the gate movement simulation.

Technically, the working process of this system begins when the user accesses the Blynk IoT application that has been installed on the smartphone. The app provides control buttons to open and close the gate. When the user presses the "Open" or "Close" button on the app, the command is sent over the internet network to the ESP8266. ESP8266 then translates the commands and activates the DC motor responsible for simulating the movement of the gate.

To ensure the responsiveness and accuracy of the system, several test parameters are carried out, including:

1. Connectivity and Latency Testing is conducted to measure how fast ESP8266 receive and execute commands from the Blynk IoT application. The average response time is calculated to ensure the system works in real-time without significant delays.
2. DC Motor Movement Accuracy The DC motors used are tested with power and load variations to ensure that the gate can move forward and backward as per the given command without any mechanical or electrical interference.
3. Reliability of IoT Communications The test also includes the stability of the internet connection used in this system, by checking whether ESP8266 can still receive commands despite network fluctuations.
4. Power and Energy Efficiency Testing The power consumption of ESP8266 and DC motors is measured to ensure the system can work efficiently in the long run without wasting energy.

The results of all tests show that the system works well, where the gate can respond to user commands in a short time, with stable and accurate movement of the DC motor. The reliability of the system is also quite good, as long as the internet connection is stable.

Table 1. Gate Simulation Test Results

Blynk's Order	Responds	Result
Opening the Gate	Receive	Gate opens with simulation of wheels rotating forward
Closing the Gate	Receive	The gate closes with a simulation of the wheel rotating backwards

Garage Simulation Test Results

After experiments and tests, it was found that the garage simulation feature was working according to its function. Where when there is an object detected by the ultrasonic sensor, the garage will not immediately open, this is to anticipate that the garage will not be used by other people. When the user gives a command to open or close the garage through the Blynk IOT application that has been installed on the smartphone, the ESP8266 will receive the command over the internet network and will forward it to the MG90S Micro Servo to open or close the garage.

Table 2. Garage Simulation Test Results

Sensor Ultrasonic	Responds	Blynk's Order	Result
There is an object	Receive	Opening a garage	Open Garage
No There is an object	Receive	Closing the garage	Closed garage

Door Simulation Test Results

After experiments and tests, it was found that the door simulation feature was working according to its function. Where when the user gives a command to open or close the door through the Blynk IOT application that has been installed on the smartphone, the ESP8266 will receive the command via the internet network and will forward it to the Micro Servo MG90S to open or close the door.

Table 3. Door Simulation Test Results

Blynk's Order	Respon	Result
Opening the Door	Receive	Open Door
Closing the Door	Receive	Closed Door

Clothesline Roof Simulation Test Results

After experiments and tests, it was found that the clothesline roof simulation feature was working according to its function. Where when the weather conditions are dark, the LDR sensor will provide a response to move the servo to cover the roof of the clothesline before it rains. And when the weather is bright, the LDR sensor will respond to the servo to open the roof of the clothesline.

Table 4. Clothesline Roof Simulation Test Results

Sensor LDR	Response	Result
Cloudy Weather	Receive	Covered Clothesline Roof
Bright Weather	Receive	Open Clothesline Roof

Light Simulation Test Results

After experiments and tests, it was found that the lamp simulation feature was working according to its function. Where when the state is bright, the LDR sensor will respond to the relay so that the light cannot be turned on. When it is dark, the LDR sensor will respond to the relay to turn on the light. In the dark, users can also give commands to turn off the lights through the Blynk IOT application that has been installed on the smartphone, then ESP8266 will receive the command through the internet network and will forward it to the relay to turn off the lights.

Table 5. Light Simulation Test Results

Sensor LDR	Response	Blynk's Order	Result
Dark State	Receive	Light/ Turn off	Lights On/ Die
Bright Condition	Receive	Light/ Turn off	Lights Off

Overall System Analysis

Based on the test results, the entire prototype system has run according to its function. The system is able to run several available features and is able to provide information to the user's smartphone well. There are several features in this prototype, including a simulation of a gate driven by a DC motor and a simulation of wheels. Then the door and garage features that open and close using the MG90S servo. Then the feature of the clothesline roof which works by opening and closing using the MG90S servo. And the last feature is the light where the relay works will turn the lights on and off. This system also works by using the internet network through the control of the blynk application on a smart phone.

The use of electronic components for the prototype scale in this final project has been able to provide an overview of the smart home that can be used as a reference for real scale.

CONCLUSIONS AND RECOMMENDATIONS

From the results of the tests that have been carried out, it can be concluded that the entire Iot-Based Smart Home System Prototype Using ESP8266 Microcontroller can work according to its function and can be used in smart home prototype references. The results of the overall testing of the feature are quite reliable and stable in carrying out its duties. Suggestions for working on this prototype to be better are as follows:

- a) Increase the use of real scale.
- b) Addition of other features (such as fans, alarms, etc.).
- c) Stable internet connection

FURTHER STUDY

As a development of the IoT-based Smart Home System Prototype research using NodeMCU V3 ESP8266, further research can be focused on improving system efficiency, data security, and integration with artificial intelligence (AI) technology to improve system automation and adaptability. Some aspects of further research that can be done with the optimization of Power Consumption in Smart Home Systems

1. Using energy-saving sensors or low-power communication protocols such as MQTT to reduce the power consumption of microcontrollers and actuators.
2. Added a power-saving mode to the NodeMCU ESP8266 so that it can enter deep sleep mode when there is no activity that requires high power.
3. Using alternative power sources such as solar panels to make the system more environmentally friendly.

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