Bachelor of Science in Computer Science & Engineering

IoT Based Controller Device Design Using NodeMCU and Cloud Server to Improve the Device's Performance and Security

by

Md. Ihsanul Haque

ID: 1504104

Department of Computer Science & Engineering

Chittagong University of Engineering & Technology (CUET)

Chattogram-4349, Bangladesh.

May, 2021

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Submitted in partial fulfilment of the requirements for
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in Computer Science & Engineering

by

Md. Ihsanul Haque
ID: 1504104

Supervised by

Dr. Muhammad Ibrahim Khan
Professor
Department of Computer Science & Engineering

Chittagong University of Engineering & Technology (CUET)
Chattogram-4349, Bangladesh.

The thesis titled '**IoT Based Controller Device Design Using NodeMCU and Cloud Server to Improve the Device's Performance and Security'** submitted by ID: 1504104, Session 2019-2020 has been accepted as satisfactory in fulfilment of the requirement for the degree of Bachelor of Science in Computer Science & Engineering to be awarded by the Chittagong University of Engineering & Technology (CUET).

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Acknowledgements

At first, I would like to thank Almighty for providing me the strength to finish this work. This thesis allows me to express my gratitude to those who had given me support and help throughout this implementation. The successful completion of this thesis would be incomplete without mentioning people whose ceaseless cooperation and encouragement made it possible. I am grateful to my honorable thesis Supervisor Dr. Muhammad Ibrahim Khan, honorable Professor of Computer Science and Engineering, Chittagong University of Engineering and Technology, for the guidance, inspiration, and constructive suggestions helpful in the preparation of this project. I also convey my gratitude to Professor Dr. Md. Mokammel Haque, Head of the Department of Computer Science and Engineering, Chittagong University of Engineering and Technology, for his kind advice. I am also grateful to my external, Dr. Mohammad Shamsul Arefin, Professor, Department of Computer Science and Engineering, Chittagong University of Engineering and Technology, to review my thesis work. I would also like to extend my gratitude to all of my teachers for their valuable cooperation in every step of mine during the four years of the learning stage. Finally, I would like to thank my parents for supporting me the entire life. Without their encouragement and support, it would not be possible to make this achievement.

Abstract

At present Internet of things (IoT) has become a common phenomenon all over the world. Technology makes the world too much closer and easier day by day by applying IoT technologies. To create an IoT environment, we need an IoT controller device or switch. This project's main purpose is to design a more effective device using a better microcontroller and server to ensure security also. For this, the NodeMCU has been choosen which is comparatively a new microcontroller, and use Google Firebase server for real-time operation. Other components were carefully selected to get better results. Sensors and other loads will be connected with the NodeMCU through the relays. The relays are like switches for the systems. By On/Off these relays, we can control the other devices. For the interface issue, a web page and a mobile application will be used. The interface and the hardware (circuit board) will be connected by a server which will ensure the security of the whole system. The project is cost-efficient and can perform better than local devices (like SonOff). It is more secure and fast than the Arduino-based IoT controller device. NodeMCU is also less power-consuming than the Raspberry Pi. The printed circuit board of the controller is smaller in size using surface-mounted components. The user interface of the web dashboard and mobile app is user-friendly and also easy to use. This device can easily install in the local electric system and the operation process of the IoT environment is quite easy.

Keywords— Internet of Things, NodeMCU, Firebase, Printed Circuit Board, Proteus, Service Set Identifier

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Chapter 1

Introduction

1.1 Introduction

Internet of Things (IoT) is a widespread network of physical things that can share with the network. It is a system of interrelating anything like device, people, animal, etc. This technology is the backbone of the smart home/office environment and many other modern facilities[1]. Smart use of this technology can save power, efforts, and it is also economically beneficial. IoT devices can reduce the risk of unwanted accidents at home even anywhere. By one estimation, by 2020, over 50 billion such devices may be developed around the world in the next few years[2]. Big companies like Google, Apple, Amazon, Alibaba, etc. are trying to develop more advanced devices of IoT. Because IoT technology will lead the future. As IoT devices make people's life easier, people are becoming more interested day by day. So, there is huge scope in this sector.

1.1.1 Basic Concept of IoT Controller Device

To build an IoT environment, we need to use an IoT controller device. A controller device needs a microcontroller/microprocessor (Arduino, NodeMCU, etc.), relay, transistors, sensors, and actuators. The microcontroller has to connect with the power supply using a relay. The relay is used to switch loads. The microcontroller gathers necessary information using sensors. A web server or mobile application will send the commands through the internet to the microprocessor to operate the tasks. To develop an IoT environment, a controller device and a server play the main role. So, the main task is to design a circuit and then connect it with a server through the internet[3].

The previous works on the IoT automation device mainly used the Arduino and

Bluetooth signal to operate. Some projects have been done by using other microcontrollers and wireless signals. But they have many issues. This thesis goal is to try to build an IoT controller device using NodeMCU and the advanced circuit works to improve the performance.

1.2 Framework/Design Overview

In this report, it will be discussed how an effective IoT device can be designed by using NodeMCU and other circuit components[4] It will be explained how to use the cloud server and frame to control the connected devices through the internet.

First, we have to complete the circuit design and implementation part properly. For this, every component needs to be connected with the NodeMCU. We use relays to supply power to the microcontroller and with the loads A custom web

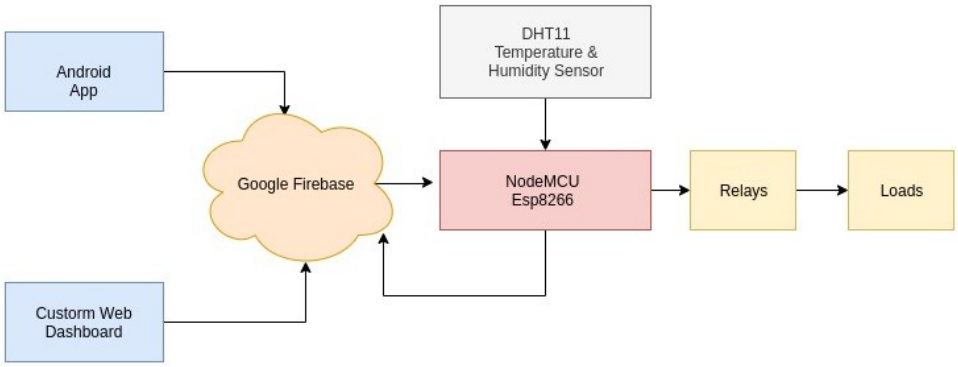

Figure 1.1: Diagram of the System.

dashboard and android app have been created for the interface system. Then the hardware and software part have been connected using Firebase which helps to provide secure and also real-time operations.

This is how the design will be done and combine the whole system.

1.3 Difficulties

The main problems of this type of project are efficient implementation, real-time operation, and security. Cost efficiency is another important difficulty for implementing IoT based environment. An IoT controller device has to be consistent in its performance. Maintaining consistency is a big issue in this sector.

Using Arduino and Bluetooth signals for an IoT environment cannot ensure the required consistency. But this combination is well cost-efficient. The operational range is very tiny. Using Arduino and web server can enlarge the system range[5]. But it has many limitations. Using a pc or small version of it like Raspberry Pi to build an IoT controller device is easy. But it is not cost-efficient. It is also high-power-consuming.

The NodeMCU is more advanced and one of the newest inventions in the field of the microcontroller. The module is an integrated IP stack that can give the microcontroller access to the Wi-Fi network. It is also cost-efficient and can provide good consistency.

1.4 Applications

IoT-based controller device design and performance improvement using NodeMCU has huge scope in the IoT-based technology sector.

- Improvement of IoT environment.
- It may provide better performance to perform more real-time operation from anywhere.
- Improvement of IoT device's performance.
- More cost efficiency can bring great result in the field of research.
- Monitoring and maintenance of IoT controller device can be easier.
- Security improvement can bring better results.

1.5 Motivation

To cope with the flow of present and future dominating technologies, automation is necessary. IoT has huge scope in the field of automation. The use of IoT technologies day by day. In the health sector, transportation business, robotics, farming, smart home/office automation, and where not!

To learn and try to get benefited from this technology, we need to understand the cores of the IoT. The controller device and the webserver are the core things of an IoT environment. Thus, I was inspired to do this project.

1.6 Contribution of the thesis

The main purpose of this project is to design an IoT-based controller device that is more secure, consistent, and efficient in many ways. For this, NodeMCU and Firebase serve have been selected.

The specific contributions of the work illustrated in the following:

- To develop a better IoT controller device using updated technologies and implement the system properly.
- To ensure cost-efficiency without compromising the performance.
- To ensure the security of the IoT environment that is connected with this controller device.
- This device can create an IoT environment for other devices quite easily.

1.7 Thesis Organization

The best parts of this report are sorted as follow-

- Chapter 2 describes a summary of related and previous works on IoT-based technology and control device designing.

- In Chapter 3, the methodology for the controller device design and performance improvement is explained. For this, the NodeMCU is the key component here.
- Chapter 4 explains the results and discussions for the proposed device.
- The overall summary of the project is explained in Chapter 5. It also provides some future recommendations.

1.8 Conclusion

This project's goal is to develop an IoT-based controller device using NodeMCU and try to improve the performance of the system and also link it with a more secure server like Firebase. This introduction part contains the basics of the whole project. It also describes the thesis organization which is described in the other chapter's summaries.

Chapter 2

Literature Review

2.1 Introduction

The use of IoT technology is increasing day by day. For this reason, research scope and interest in this sector are increasing. This section describes a summary of related and previous works on IoT-based technology and control device designing. Some implementation challenges will be discussed in the later part of the literature review. These reviews and analyses will help to improve this project works.

2.2 Related Literature Review

The previous works in this field were mainly Arduino using Bluetooth signal-based projects[6]. These systems normally use android apps that can get ready-made and so they can be easily hacked.

Here are some previous and related works that are related to this project.

Sheetal Prusty[6] represents Arduino-based home automation by using Bluetooth signal and Android application. This work used the android application as interface and command sender. The Bluetooth signal has a short-range to cover which can be a big issue.

Some works have been done by using Arduino, wi-fi signal to build the connection. G. Mahalakshmi and M. Vigneshwaran[4] represent the IoT Based Home Automation Using Arduino using wi-fi signal and Android application. Here, the router was a key device for connecting the circuit with the internet.

Some works have been done by using Raspberry Pi instead of Arduino. It can ensure real-time speed and security. But it is not quite cost-efficient and there are

some maintenance and power absorbance issues. A. Sinha and R. Tatikonda[7] proposed IoT-based automation using Raspberry Pi where Raspberry Pi is the controller device and everything is connected with it.

NodeMCU is a comparatively new module for the IoT-based sector. R. Mahindra, M. Prakash, S. Ghosh[3] represented an IoT Based Home Automation using NodeMCU with a mobile application. Many researchers are trying to design a more efficient circuit with an advanced microcontroller like NodeMCU. Server security improvement is another hot topic nowadays. Some research papers have been published recently about the faster implementation of IoT environments.

2.3 Conclusion

The number of research and project on IoT-based automation is increasing every year for its importance. So, doing a project on IoT-related works has a good scope in present and also for the future. Reviewing some related works have helped us a lot to understand the recent and current situation of IoT controller device design process.

We have discussed the challenges that we have faced to implement the hardware and software tasks in the next part of this section.

2.3.1 Implementation Challenges

It is a challenging task to design an effective IoT controller device because it controls the whole IoT environment and maintain connection among the other devices. It also requires a server and few coding works to complete the task.

- We tried to design a well-combined circuit diagram using Proteus software and then created a 3D model. Then we went for the PCB design part. When we got the PCB circuit, we combined the microcontroller and other equipment on the board. This part was highly challenging and required effort and corrections repeatedly.
- Next, we went for the interface and server part. This part was highly challenging because the security of the IoT devices depends on this. This

part also combines the hardware with the internet signal and completes the IoT environment[8]. For this, we used HTML, CSS, Bootstrap, Vue.JS, Arduino IDE, Google's Firebase for the real-time database, and MIT App Inventor for making and connecting firebase to the application.

Chapter 3

Methodology

3.1 Introduction

The microcontroller is the central unit of this project. Here, we use NodeMCU. It will gather data and maintain the connection with the hardware and server to run the IoT environment properly. It has two main parts such as design the hardware and ensures secure server connectivity. NodeMCU will be connected with the power supply through a relay.

3.2 Diagram/Overview of Framework

The Proteus 8 Professional software has been used to draw the circuit design. Proteus is used for circuit schematic and PCB design. With the help of the 3D model of the proteus software. 3D model of the circuit board was also be seen at the same size. Schematic of the whole circuitry.png After creating the

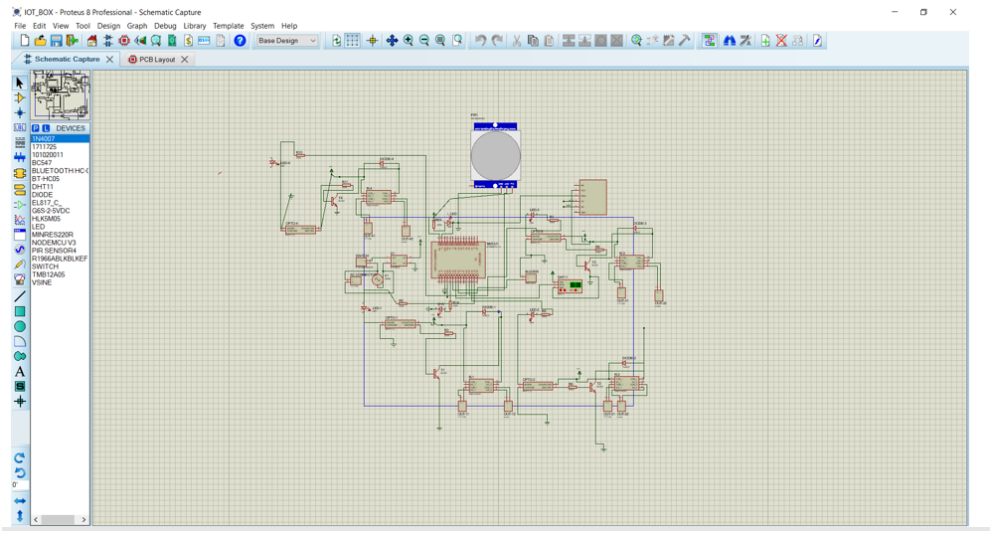

Figure 3.1: Schematic of the whole circuitry.

Schematic of the whole circuitry, we went for the PCB layout of the IoT controller device. This helped to find a proper PCB design for this project. The next step

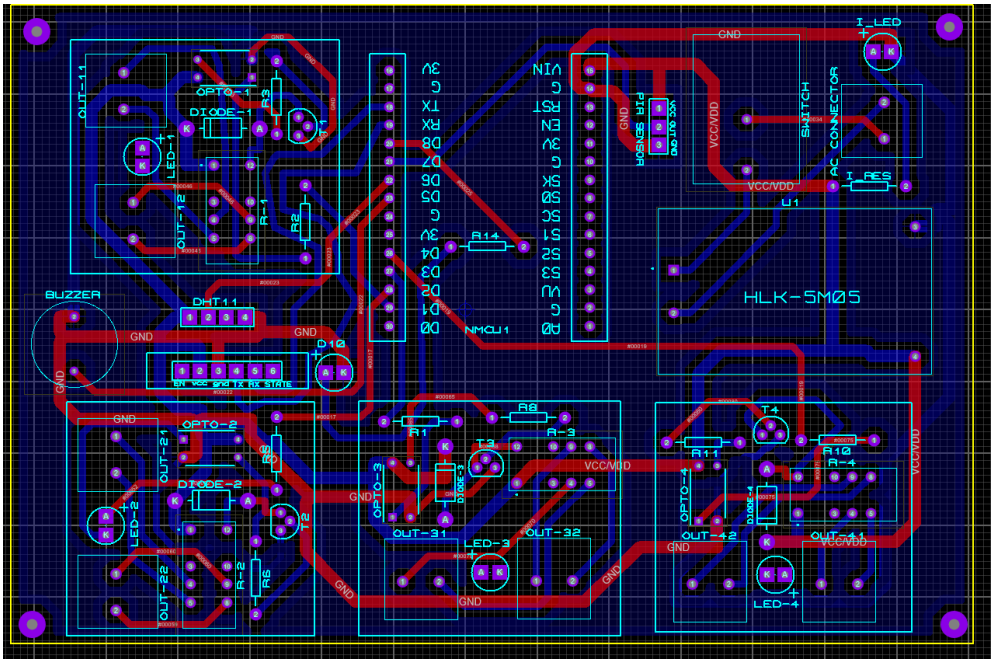

Figure 3.2: PCB layout of the IoT Controller Device

was the 3D design of the circuit board. For this, we used Proteus software. we used different footprints (NodeMCU, Relay, etc.) from the components search engine's snapEDA. This 3D model helped us to implement the circuit board works in practical. The final part of the device designing is soldering the whole

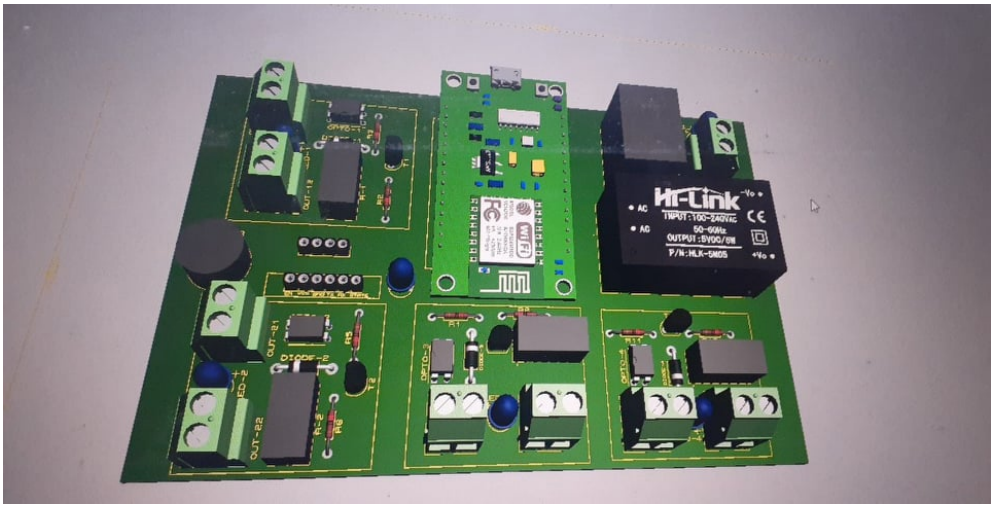

Figure 3.3: 3D design of the circuit board

circuit and combine all the components in the circuit board. This was the most technical task of this project. It represents the real size and shape of the IoT

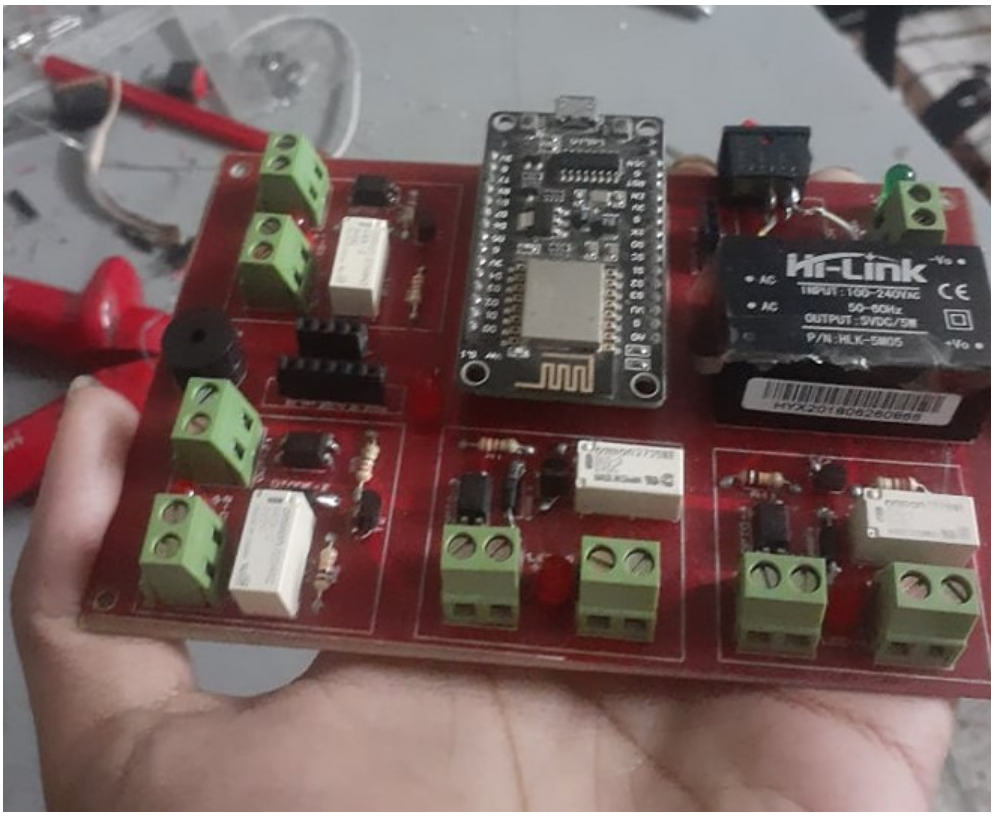

Figure 3.4: After Completing Soldering the whole circuit

controller device. we were always careful to complete this part precisely. Any loose connection can bring a worse situation for this. The interface and server part will be discussed in the detailed explanation part.

3.3 Detailed Explanation

The main components are needed for the electronic system are –

3.3.1 NodeMCU (ESP8266):

NodeMCU (ESP8266) is a low-cost IoT platform. It has built-in wi-fi for communication over the cloud[9]. It is the main linker between the device and the server. ADC power supply is used for the NodeMCU[10]. This microcontroller searches for the preset SSID (Service Set Identifier) and connects automatically to the Internet. All the pins of the NodeMCU are shown in Fig-3.6.

Figure 3.5: NodeMCU (ESP8266).

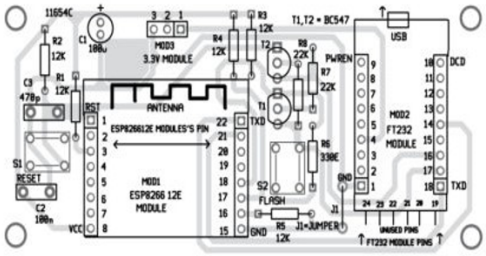

Figure 3.6: Pins and connection points of NodeMCU.

3.3.2 DHT11 Temperature and Humidity Sensor:

It is a low-cost digital sensor that is a capacitive temperature and humidity sensor. DHT11 uses a thermistor to measure surrounding temperature and humidity. It is quite easy to use. This sensor can get data from the surroundings every 2 seconds.

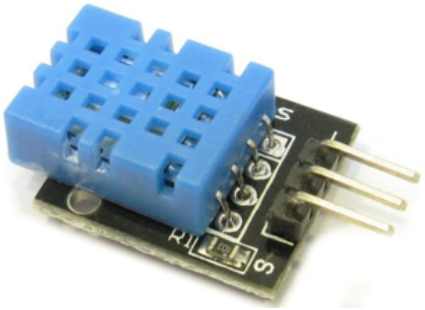

Figure 3.7: DHT11 Temperature and Humidity Sensor

3.3.3 Relay Module:

Relay is used to switch electric appliances. This type of component can be operated by a relatively small electric current that can turn ON or OFF a much larger

electric current. Using the circuit is safer as there is not any direct connection between NodeMCU and AC power supply.

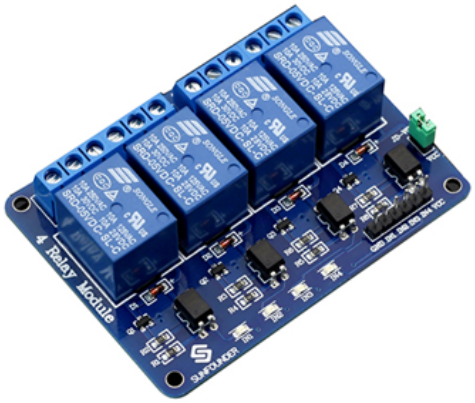

Figure 3.8: Relay Module

3.3.4 Buzzer:

It is an audio device that is used to signaling based on the applications. Buzzer converts audio signals into sound signals. In this project, the buzzer is used to notify when any distortion will have happened.

Figure 3.9: Buzzer.

3.3.5 LED

It is a Light Emitting Diode. In this project, it is used to observe the relay. When the relay gets the voltage, its connecting LED (RGB LED 5mm) glows and we can understand the relay gets the applied voltage.

Figure 3.10: LED

3.3.6 Voltage Regulators

Voltage regulators provide a constant output voltage from the varied inputs. That's why these are common in circuit works. We use two voltage regulators in this project.

- 7805 Voltage Regulator

From the 7805, '78' means this voltage regulator is a positive regulator. '05' means it will provide +5V output.

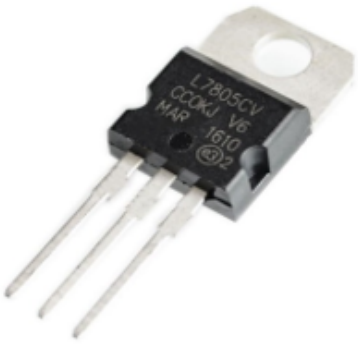

Figure 3.11: L7805 Voltage Regulator

- AMS1117 SMD Voltage Regulator

It is a popular 3 pin voltage regulator. The output voltage can vary from 1.5 to 5V. This IC has commonly used in Arduino-based projects.

Figure 3.12: AMS1117 SMD Voltage Regulator

3.3.7 Diodes

These diodes are used for the circuit design.

- Diode 1N4007
- Zener diode 3.3V
- 1N4735 Zener Diode

3.3.8 Transistors

Transistors are important components of the circuits. These transistors are used for this IoT project.

- BC547 NPN Transistor
- BC557 PNP Transistor
- 2N2222 NPN Transistor

3.3.9 Resistors

Resistors are widely used in circuits. Those can resist the flow of current. This phenomenon can help to save a device from the overflow of electricity. Different types and number of resistors are needed for different uses. These resisters are used for this project.

- 1k Ohm ¼W Resistor
- 10k Ohm ¼W Resistor
- 220 Ohm ¼W Resistor

3.3.10 Push Switch

It is a kind of switch that can change the circuit operation temporarily when it is pushed physically. The switch returns to its position after a push. Here, the push switch is used as the power button. So, it can disconnect the power supply immediately when it is necessary.

3.3.11 Connecting Wire and Breadboard

These components are used for testing purposes. Before implementing the circuit design physically, every component has been installed on the breadboard and check their connections and performance.

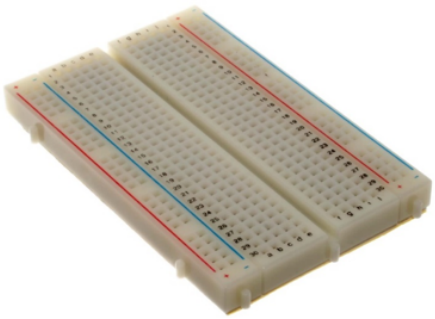

Figure 3.13: Breadboard

To connect all components, we use two types of connecting wire. They are,

- Male to male jumper wire
- Male to female jumper wire

These are the component for our proposed device. We put them on our custom-designed circuit board and do the wiring to complete the hardware part of the device.

3.3.12 Interface and Web Server

Interface and server are a key part of the IoT device. It is the face and backbone of the whole system[11]. We can monitor and give commands through this. For this, custom web dashboard has been built.

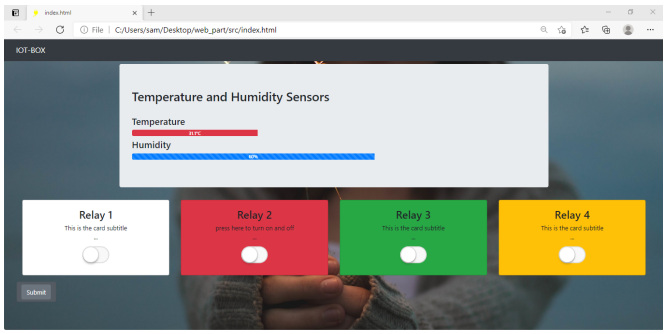

Figure 3.14: web page

For the front end, HTML, CSS, Bootstrap were used. And for the back end, Vue.Js and Google's Firebase for the real-time database were used. The User can watch the temperature and humidity condition, four relay buttons, and a submit button on the front web page. A mobile application has been built using MIT App Inventor. It uses Java programming language to create an application for mobile devices. This application is linked with the custom web dashboard.

Figure 3.15: Mobile Application

This application can be used on any android phone or device. When we will

change (ON/OFF) any relay button using the mobile application, the web page will also update itself.

3.4 Conclusion

The methodology is the key part of a thesis or project. Here, how the device was designed and also the interface and server parts have explained. In the detailed explanation part, all the components that was used for this project have been discussed.

Chapter 4

Results and Discussions

4.1 Introduction

In this section, the results of this project will be discussed. Also, some result-related topics will be discussed like social and environmental impact.

An IoT controller along with a web dashboard and an app was developed in this project. This controller can be used to control existing household electrical appliances.

The overall size of the controller is sufficiently compact so that it can be placed inside some traditional electrical boards and can be easily integrated with existing home appliances. Using the web dashboard and mobile app the controller will be accessible from anywhere on the globe with an internet connection.

Total cost for this project work is below

Table 4.1: Cost of this device design.

Component	Price(Taka)
ESP8266 NodeMCU	450
5V Relay(OMRON)	240
Breadboards l	200
Sensors	300
Transistors	50
HLK5M05 AC-DC Isolated Power Supply Module	600
Zener Diode 3.3V	10
Switches	100
Resistors	20
Jumper Wire	100
PCB Printing Cost	700
Copper Wire	100
Others	500
Total	3370

4.2 Impact Analysis

4.2.1 Social and Environmental Impact

In this project, we use fewer electrical components compare to similar projects. The NodeMCU requires less power and runs the automation process for the other devices. So, this project can help to reduce power consumption. This project is also well cost-efficient. This IoT device can provide any device an automation process when the device will be connected to it.

4.2.2 Ethical Impact

IoT technologies have these main ethical issues.

- Privacy
- Information security
- Physical safety

These issues have a great impact on this project. We always concerned about these issues when doing the project works. We tried to develop a new server system to improve information security. This device only gathers the humidity and temperature of its surroundings. We also included an emergency button to stop the device immediately when it is necessary.

4.3 Evaluation of Performance

The features of the IoT controller device is below:

Table 4.2: Features of the Controller.

Features of the Controller	
Current Rating	<1amp
Voltage Rating	5V
Relay channnel	4
Manual control	Yes
Web Dashboard	Yes
Mobile app	Yes
Compatibility	Compatible with Traditional Electrical wiring

If we want to compare with the local market IoT controller device, we will see some IoT switches like SonOff. The price of that device is about 1500 taka. But the main problem for this device can operate only one lode. But our IoT controller device can operate 4 loads along. This device can be manufactured for under 3000 takas only and that is low compare to other international products. But the performance of this device is really impressive and promising.

The security feature for this device is better than the Arduino-based device and local server-based devices. This device uses Firebase for real-time server operations which is a Google product and it ensures the security of the system.

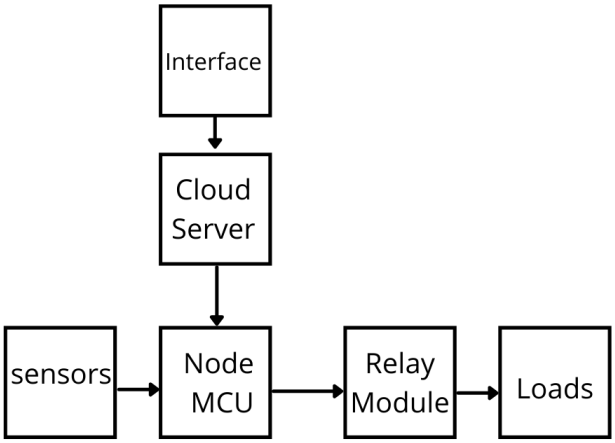

Figure 4.1: Block diagram of the whole system

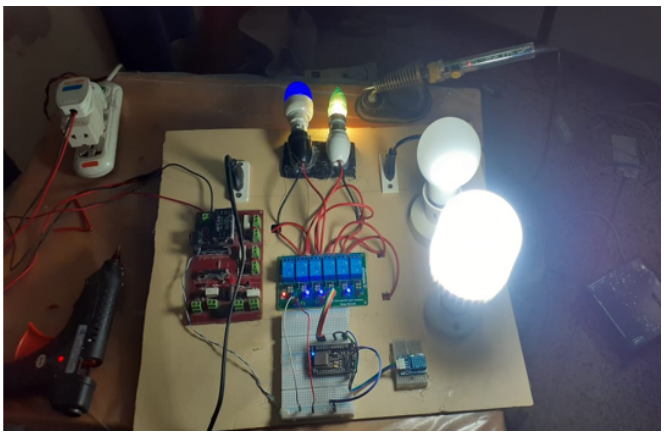

Figure 4.2: Practical operation testing

The NodeMCU is the microcontroller of this IoT controller device. It is connected with the sensors, cloud server, and relay module.

The interface is connected with the could server which is Google Firebase for real-time operations. For the interface of the system, a web page and mobile application have been designed.

Loads are connected with the relay modules. The relay module is like a switch. It controls the power supply of the loads that are connected with the system.

4.4 Conclusion

In this part, the result and impact of the IoT controller device have discussed that the system was designed using NodeMCU and Firebase server. The features of the device also have discussed by using a check table. The main advantage of this device is, it is easy to implement and operate in a traditional electric system and creates a secure IoT environment easily.

Chapter 5

Conclusion

5.1 Conclusion

This project's goal is to develop an IoT-based controller device using a micro-controller and try to improve the performance of the system. Also, link the device with a cloud server to run a secure and fast operational process which can be more effective to use in the real world.

The NodeMCU is used as the micro-controller instead of Arduino or Raspberry Pi because it is advanced and less power consuming and also a better performer. The price is affordable and NodeMCU is also durable. For the server, Firebase server is used which is more secure than other open-source servers. It also ensures real-time IoT operations. There were some implementation challenges that we faced during doing the hardware, server, and interface works. To solve these, we tried to design a well-combined circuit diagram using Proteus software and then created a 3D model. Then we went for the PCB design part. The sever and interface part was highly challenging because the security of the IoT devices depends on this. We used more secure and welly known software and programming languages to create user-friendly interfaces.

The cost of this project is affordable and also less than the similar device's costs. But the performance of the device was satisfactory. The size of the whole device requires less space and it is easy to operate also.

5.2 Future Work

This project aimed to develop a controller from scratch along with a web dashboard and a mobile app for easy control. Though the prototype works as expected, some aspects can be developed for a better quality of the controller device. The printed circuit board of the controller can be made smaller in size using surface-mounted components. The user interface of the web dashboard and mobile app can also be made more user-friendly. The Bluetooth module to run the system locally. Different types of sensors can be added for further advancement.

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