2019 International Conference on Sustainable Technologies for Industry 4.0 (STI) 24-25 December, Dhaka

IoT Based Home Automation System with Customizable GUI and Low Cost Embedded System

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***Abstract*—This paper presents a customizable GUI and an inexpensive embedded system with internet connectivity for monitoring and controlling several devices and home appliances remotely, using android-based smart phone application or computer-based application. The system consists of a customizable GUI that facilitates the users' demand; micro-controller helps convey the user input to the system; wireless connection to the devices under the system. This study explains the overall design of a low cost Home Automation System (HAS) with wireless (WiFi) system (Internet). This HAS is designed to assist and provide support in order to fulfill the needs of children, elderly people and common disabled individuals in their home. In addition, the smart home concept based on IoT improves the standard of living at home. The main control system implements a client server relationship to provide remote access from smart phone through wireless Internet technology. The switches of the electrical appliances are synchronized with the entire control systems in a way that every user interface displays the real time status of the existing switches. Using EEPROM, the last status is preserved and in case of power cut, the system will retain the last-known reading when it recovers from a sudden calamity. The novelty of the system is it gives permission to multiple users at the same time to access the system and change their priority. This system is designed with customizable GUI, inexpensive embedded system, and it is easy to install, control and monitor with an array of electronic devices widely used in everyday home chores.**

***Index Terms*—Inexpensive Embedded System, IoT, Home Automation, Customizable GUI, Home Appliances Control and monitoring.**

I. Introduction

The use of various sensors to collect uninterrupted data, then based on the collected data, it is possible to remotely control and monitor devices. The whole concept of centralizing elements to the Internet is known as IoT [1]. With growing technology, most of the homes use electronic appliances such as fan, light, air conditioner, and so on. Smartphones are very common for everyone nowadays. IoT creates a bridge between these home appliances and Smartphones through wireless connectivity [2]. Hence, using mobile as a remote controller, the home appliances will enhance the efficiency and simplicity of the HAS. The smartphone has the capability of connecting to the electronics devices using various well-tested and widely used wireless technologies. An android application has the potential to incorporate the system and forward the signals via web.

To increase the security feature of the Android application, user authentication and password protection have been implemented. In this system, all the appliances are connected with a mother server which lets us control from an android application. Besides, it allows the full control from a conventional PC [3], [4]. ESP8266 (NodeMcu) has been used as the micro-controller in this system. The connectivity of the Internet has been used for efficient connections regardless of distance and location. Through the Internet, one can control the devices from anywhere in the world. It has the potential to help the consumer as well as the government by reducing energy wastage [5].

This article is structured as follows: Section II explains the related works about the home automation using the embedded system; Section III represents the proposed system overview; Section IV provides a methodology; Section V explains Result and analysis; Section VI concludes the paper.

II. Related Works

R. A. Ramlee [6] introduced wireless bluetooth to develop a smart home system that assists disabled people to conduct their daily liveliness comfortably and safely. The technology of controlling home appliances by the remote controller or through the internet is introduced in the research using ZigBee by Khusvinder [7]. Home automation system using Bluetooth technology with a cell phone is proposed by R. Piyare and M. Tazil [8] with very low cost. The problem of such home automation system for only software level is solved by Neng [9]. He presents an architecture with a dedicated network for home automation system that enables user to control devices, although the range was limited in size.

We observe that these proposed systems have few limitations including security, user-friendliness - they all fail to let the user customize according to their needs and wishes. Many of the systems do not allow customization of the GUIs for a specific MCU. Besides, many fail to deliver concrete plan on how to handle multiple users.

Mtshali et al. proposes a system that connects devices such as camera, smart phone, and other ordinary items to digital assistants such as Siri from Apple devices, Google Assistant from Android, Microsoft's Cortana to help physically challenged people in their home management [10]. Mao et al. proposes a system that takes the help of 3G or 4G technology and works with web gateway such as cloud servers [11]. However, these systems are quite expensive and does not help

978-1-7281-6099-3/19/$31.00 ©2019 IEEE

when it comes to saving resources as they are quite power-hungry and lacks user-friendly features.

III. Proposed System Overview

The architecture of the system consists of a Server and the Main Control Unit (MCU). MCU includes an ESP8266 NodeMcu and an input/output Interface (IOI) unit. NodeMcu which is the size of a pen-drive, is equipped with Relay Module to control high voltage appliances. Operating MCU is easy and can be done through an Android phone or a PC. Android phone and computer is connected with the central server. Server sends data to the devices and the devices also send data to the server, whereas the MCU is connected with the server in one way communication module. Server data can be sent to the MCU only. The MCU decides on behalf of recently received data what the next action is. Figure 1 shows the system. The GUI is designed and created for the android phone on Android Studio while our PC segment is designed using PHP and JAVASCRIPT. The GUI acts as the medium among the user, server and the MCU for both control and monitor of the entire system to show the live status of the home appliances and if necessary, send control signal to the appliances. In this prototype system, it has two different outputs; one being light and other is socket. For light and socket, multiple users can monitor current status and control them simultaneously.

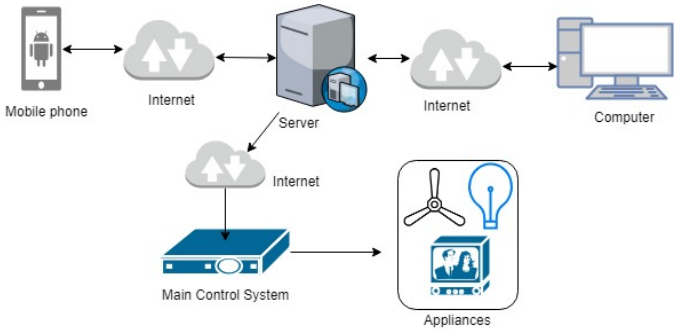


Figure 1: General Architecture of the proposed model

IV. Methodology

The overall process in the flow diagram in Figure 2 shows status of the devices, such as, is the device currently being used or the device is switched off on the customizable GUI. The GUI has made it possible for the users to access simultaneously from a PC/laptop or a smartphone. This includes considerable options, such as, using a web browser, application of virtual and remote networking, and so on. Consequently the system has become a flexible and multipurpose system. The GUI is very user-friendly and easily re-configurable setting makes it simpler and easier. Any user is capable of customizing the GUI at a time for all the devices which are connected with the MCU. Figure 2 shows the overall system flow chart. Each GPIO pin defines a button to control functions, such as switching a light On or Off and socket in the prototype system. Figure 4 shows the prototype of implemented system.

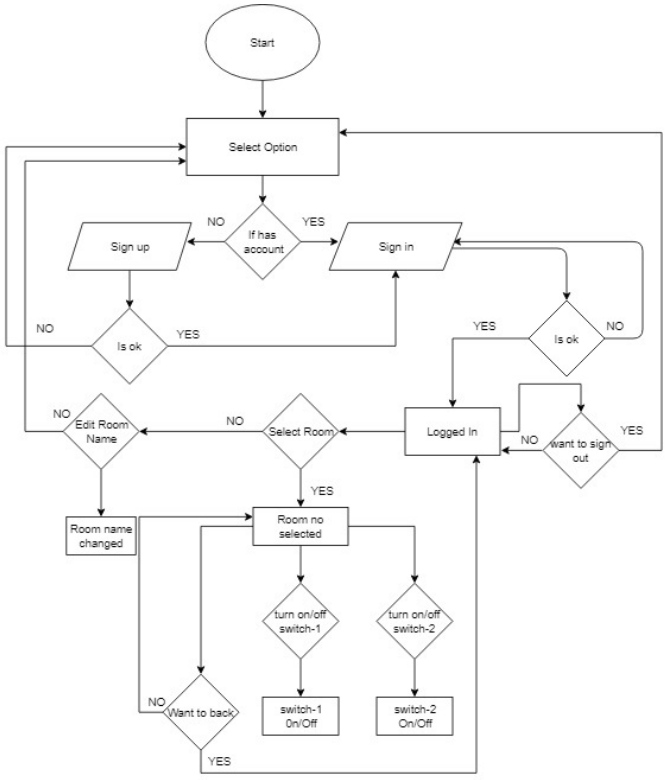


Figure 2: Overall Process of GUI of the proposed model

Each GPIO pin defines a button to control function turn on/off the light and Socket in the prototype system.

V. Result and Analysis

The full result and the analysis of the outcomes for the entire system are discussed in this section. Figure 5 is the actual implementation for the proposed model. We have split the outcome into four parts. They are: hardware outcome, server outcome, graphical interface outcome, and MCU outcome. A user can control multiple devices from an account.

A. Hardware Outcome

To examine the overall system functionality, the MCU of the proposed prototype were linked with a light bulb and socket. In the system, the IOI unit consists of a 4 channel relay switching module circuit for controlling high voltage AC appliances. Server sent a JSON format file to MCU and MCU correctly made decision on the basis of this data. The GPIO pins of ESP8266 used to connect IOI unit, and table 1 shows the assigned jobs with respective input/output for each pin of the GPIO [12].

Table I: List of assigned jobs for each GPIO pin associated with input/output.

Input	Button	GPIO	Output
Light	Switch1-on/Switch1-off	4	Light is on and off
Socket	Switch2-on/Switch2-off	0	Socket is on and off

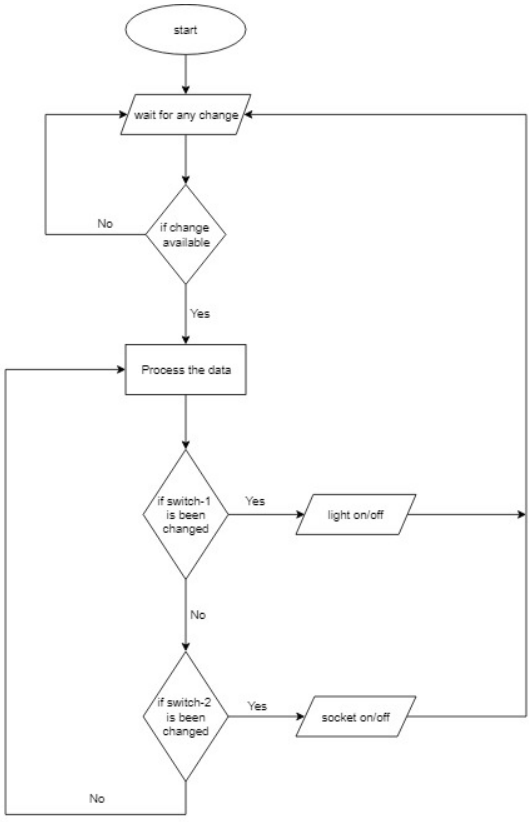


Figure 3: The overall process in MCU for the prototype model

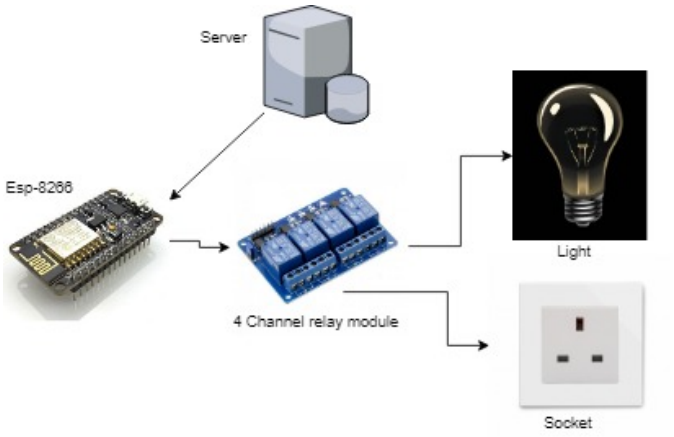


Figure 4: Prototype of the proposed model

Each GPIO pin define a button to control function turn on/off the light and Socket in the prototype system. Figure 4 shows the prototype system.

B. Server Outcome:

Server sent data to connected MCU and GUI frequently. User also sent data to server from connected GUIs for any change. Once a request is received, server can detect whether the user is authentic or not. Figure 6 shows an example of such user request. Server maintained a database for each user. Figure 7 displays the example of internal database. Server

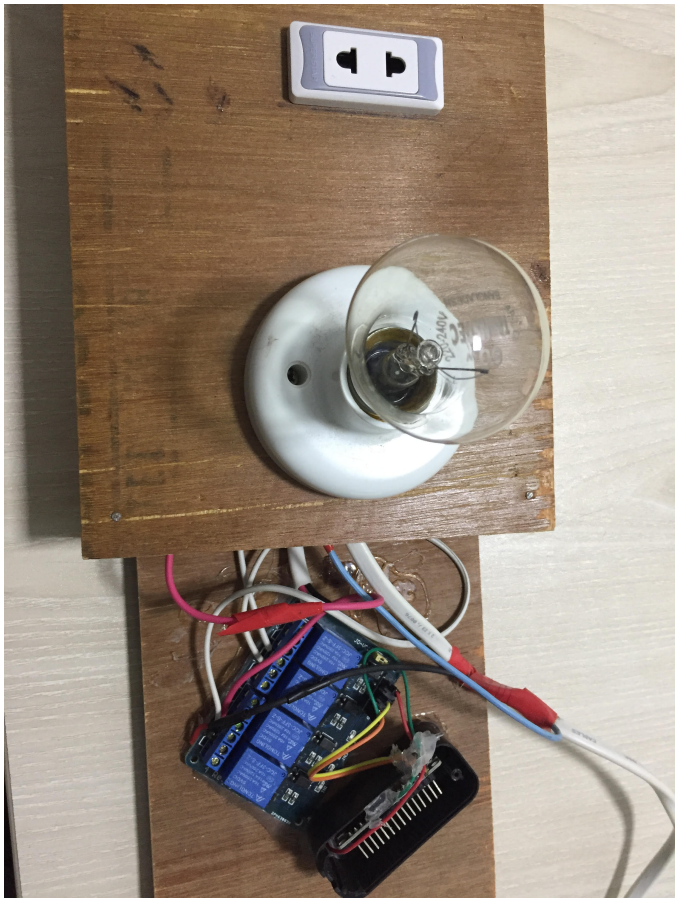


Figure 5: Implementation of our prototype

can maintain multiple users for a specific MCU and also for multiple MCU for different GUI. Server maintain multiple

```
http:// ... /updatesw2.php?room=room&light=on&id=****&pass=****
```

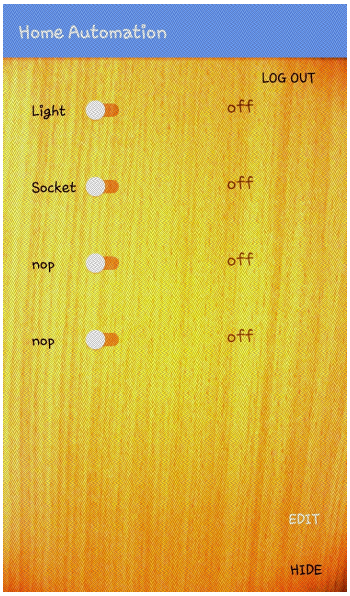
Figure 6: Request of the Server

Options

	id	light	fan	pass	switch3	switch4
Edit Copy Delete		off	off		off	off
Edit Copy Delete		off	off		off	off
Edit Copy Delete		on	off		off	off
Edit Copy Delete		off	off		off	off
Edit Copy Delete		off	off		on	off
Edit Copy Delete		off	off		off	off
Edit Copy Delete		off	on		on	on
Edit Copy Delete		off	off		off	off
Edit Copy Delete		off	off		off	off

Figure 7: An example of internal database

users for a specific MCU and also for multiple MCU for different GUI.



(a) Smartphone GUI

(b) Web browser and computer screen

Figure 8: (a) GUI for smartphone controlling and (b) GUI for web browser and computer screen

C. Graphical Interface Outcome:

This includes two types of GUI results. One for smartphones, another one is for web browsers. Hence, more than one user can access to control one single MCU. This also allows monitoring the current status of these switches which simultaneously updates in multiple GUIs for any change. For Smartphone users, few options such as, "Edit Room", "Edit Switches", etc. are given so that users can easily customize their GUIs based on the number of their home appliances, rooms, and these changes on GUI will appear in all the devices at the same time. This means that the whole system is interconnected. Figure 8(a) shows the GUI in Smartphone and Figure 8(b) shows the GUI in a web browser as well computer screen.

D. MCU Outcome

MCU can detect any change in the system and here, it keeps asking for log from the server. If the server receives any new instruction, it provides the MCU with the latest data. Server sends a JSON formatted data to MCU usually as the MCU

```
https://..../getdatanr.php?room=...&id=...&pass=****
```

(a) Request to server

```
{"light":"on","socket":"off","switch3":"off","switch4":"off"}
```

(b) Response from Server

Figure 9: (a) Requesting to the server and (b) Responses from the server

constantly requests for new data. Then, MCU decides on the basis of the recently received data.

The overall process follows the algorithm shown below.// The overall process is run in never ending process which ensures a user will receive full-time support. Figure 9 shows the request of MCU to server for recent update and the response JSON data.

Start MCU
Repeat Step-3 to Step-6
if *changes not occur* **then**
  back to Step-2.
else
  Request server to update data.
  Get response data from server.
  Update the current status in MCU.
  Go back to Step-2
end

Algorithm 1: Process of MCU Outcome

In Figure 3, the processes involved for the prototype MCU are described. At first, MCU will wait until a change occurs by a user in the server side. Then, MCU takes an action on behalf of the specific user demand, such as turning a light on or off.

VI. Conclusion

The proposed system illustrates the possibility of introducing a new system for a smart home concept which will also help the elderly people and disabled people. The concept of a login system will ensure the security of the system for a consumer. This system is not only limited in home automation, but also can be used for office environment. The concurrent monitoring system for multiple users will help reduce the possibility of accident, curb the wastage of energy and save our valuable time. When a user makes a change for any switch from any GUI, this system makes auto change on all other GUI. Customizable GUI makes it easier to manage all the switches. For instance, when the user presses a button from the customizable GUI on their smartphones (Android based) or from the websites, lights and sockets will turn ON and OFF respectively. In the future, many improvements are possible in the MCU, GUI, and also in the primary server. In MCU, two way communication modules can enhance efficiency of the monitoring regime, to show the status of currently connected devices. Real-time

power consumption monitoring can also be integrated in this system which can help reduce the possibility of accident, and save energy. At last, this system provides a reliable and flexible way to implement Home Automation System with low cost compared to the available systems.

ACKNOWLEDGEMENT

We would like to thank the Institute of Energy, Environment, Research, and Development (IEERD, UAP) and the University of Asia Pacific for financial support.

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