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Design and Implementation of a Home Appliance Automation Framework

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***Abstract*- The paper contains two sections. The first section explains the literature review about the existing Home automation systems with reference to the technologies used in each of them. The second section describes the proposed system's design and implementation. Traditionally, the proposed system was to automate the home electrical devices and appliances for providing ease of use to the home owners within a limited scope, but later on, the advancements in the system led to a more scalable, flexible and remotely accessible approach towards control and management of home appliances. Nowadays, home automation is becoming more of a concern of cost-effectiveness and ubiquitous access. Numerous cost-effective technologies have been proposed, which are increasingly being used, but the concern of ubiquitous access is still a matter to be solved. There are cost-effective systems based on Wi-Fi, Bluetooth, etc. technologies, but their scope is limited as the home appliances can be controlled by the user only within the range of Bluetooth or from where the Wi-Fi network is available. These limitations are paving the way to the development of systems that will support cost-effective ubiquitous access to home electrical devices and appliances in the future. The proposed system will be cost-effective as it uses the mobile phone's inbuilt SMS facility for the home appliances' automation. The proposed system monitors the status of home appliances and controls them within the GSM network.**

***Index Terms*—Automation, GSM, Android Application, Arduino, Home Appliances, Smart Phone, Short Messaging Service (SMS)**

I. INTRODUCTION

The home automation concept is an approach for controlling the home appliances. Nowadays, the automated home concept is getting everywhere. Several approaches are used to automate the home. The design of a home automation system has several issues involved in it. For easy integration of a new device into it according to requirements, the home automation system should be scalable. Its main concern should be the provision of a user-friendly interface on the user side for the convenient setup, visualization and control of the application.

The beauty of a home automation system lies in its scalability & flexibility. While all around the world different companies are involved in home automation systems' development, most of the people (i.e. in the developing countries) are unwilling to accept an integrated home automation system primarily due to the high cost & reliability issues. Different techniques are introduced, such as internet, infrared, ZIGBEE, WIFI, DTMF, and Bluetooth, in automation. Each of the techniques has its own advantages and limitations. These limitations are paving the way towards the development of more scalable and flexible automation frameworks. We want to provide a more reliable & much affordable solution.

"To develop a smart home in the Era of smartphones" is the real motivation of this project. The goal of home automation is to create an easier, more enjoyable and safer home to live in. Keeping in view the needs of home users regarding the regulation of the home, this project can be declared as a good solution so far. This Smart home system will help individuals in experiencing a smarter, flexible, safe and comfortable home environment. This project will provide convenience to all home users.

II. LITERATURE REVIEW

Home automation, or in other words, the intelligent home, home environment automation and control, smart home, home area network or demotic are some common terms which are usually referred to the concept of automating the home with the use of different technologies [1-5]. The purpose is to equip various sections of the home with an intelligent monitoring and control system and to ensure a harmonious interaction among them. This is done in a

way to provide an automated environment without much user intervention or to provide handy remote-control access, which is safer, efficient, easier, convenient and less expensive.

The journey started back in 1725 when a French investor, Basile Bouchan [1,2], had designed an automated machine for the draw loom. Home automation is thought to be an important science fiction feature for several years, but the system came into practice with the introduction of electricity in homes and the advancement in IT in the early 20th century. Similarly, remote control devices came into use in the late 1800s [3,4]. Nikola Tesla [3] had presented an idea based on the vehicles and vessels in 1898. The electrical home appliances [4] had started between 1915 and the 1920s. This resulted in a decline in the domestic servants, who were replaced by the cheap mechanical systems. Similar ideas to the modern home automation originated in the 1930s. Later on, Chicago's fair (1934) [4] in New York (1939 and in 1964-65) [5,6] had presented the idea of electrified automated homes. Appliance constructionists and the industry of construction services have implemented the remote and intelligent control technologies.

The journey continued with the building of the first wired Home (1960) in America by a hobbyist [5], but it had limited technology owing to the wired infrastructure. Later in 1966, an engineer, Jim Sutherland, who was employed by Westinghouse Electric, established his home automation system named ECHO IV [7] as a research project, which was not intended for commercialization. In 1984, the American Association of Home Builders coined the term smart house [5-7] for automated homes. This automation had invented the microcontroller, which provided a cost-effective solution to the problems lying in this journey of automation.

Late in the 1990s, the term domotics [8] was introduced, which described a system formed from the combination of informatics and telematics [4,5,9] for supporting home activities. This phrase is formed from the word informatics and domus [4,5] (Latin meaning: house). Both these terms have reference to the use of techniques used in computer and robotics in home appliances. The original idea of home automation was domotique [5], which originated in France (1980s) and domotica [5,10,11] in Spain and Italy (1990s). Although home automation was taken with great interest, there was no widespread uptake in the late 1990s, as such systems were still considered the domain of the rich or hobbyists. There were some limitations leading to the single streamlined protocol and an increase in entry cost that had put the consumer's number down. Later in 1991, a consultancy office was set up by Ad van Berlo [12] for assisting technology in the care sector. It had made switching possible from the world of medical technology to the world of care technology. Later, the field of gerontechnology [13] emerged, which aimed at providing ease to older and disabled people and to provide them with handy control so they can lead an easier and comfortable life.

Smart homes were set up by Corien in coordination with her husband in 1998 with the ambition of promoting the home automation demonstration projects, which were finished in 2000 & 2001[14-18]. A demonstration project, the Intelligent Millennium House was constructed in 1998, which is a combination of different home automation techniques, including optimization of the heating system, an intelligent security system, an automatic irrigation system for gardens, programmable door locks, along with advanced telecommunication technologies. In 2001, the breakthrough in Smart homes was seen when Van Berlos constructed the smartest home in the Netherlands. This new demonstration model was open till the end of 2001[19-25].

Home automation technology is one of the most recent and continuing developments. The up-to-date report Global Industry Analysts (GIA)on the global home automation forecasts that by the year 2015 international market for Home Automation will reach almost 2.8 billion US Dollars [1]. In [13], it was claimed that the importance of safety and accessibility, technical developments in home automation, and increasing mandates from both developed and developing countries are the main aspects for growth in the home automation market internationally. A communication protocol is used to integrate electrical devices used in smart homes. Communication protocols may run over radio frequency wireless communication or a combination of power line and wireless technologies, also on wired technologies [23,26-30], but wired technologies for making smart homes are expensive, in comparison with the latest home automation

technologies [23]. Power line communication technologies are used for home automation, which uses house wiring as a medium, but they work on the AC power of the house and can't handle higher frequencies. There are problems of electrical noise, inflexibility and comprehensiveness loss in power line communication [27,31].

Nowadays, different home automation systems range from automatic light switches to a fully integrated network for home automation, which are designed for different purposes, but they are not interconnected and interoperable [15].

Data rate demand is not an important parameter in measuring small-sized devices. For example, power consumption and reliability. [27] Explains four technologies named: Bluetooth, WiFi, certified wireless USB, and Zigbee. Bluetooth provides an authentication technique by using a 128-bit key[24,27,28]. In contrast to other technologies, Bluetooth is additionally opposed to snooping, as opposed to others (Wi-Fi, ZigBee), physical layer used FHSS and not DSSS modulation techniques, which means we must go behind the FHSS if we want to continue receiving data [22,28,29]. Trustworthiness is a less frequently discussed parameter of Bluetooth. In Bluetooth, the mechanism used on the physical layer is different from interventions and deliberate overcrowding to some extent [27]. Wi-Fi is a much-improved wireless technology these days. Previously, it was part of (W)LAN networks, but due to the newest improvements, it has become part of the (W)MAN family. In comparison of Wifi with WUSB, ZigBee and Bluetooth, the maximum execution power and memory are essential. Modern chips hold 400MHz RISC processors with 64KB-128KB caches, and use peripheral ROM and RAM [25]. Wi-Fi load is not held by the ordinary Wi-Fi USB dongles in the firmware [25]. Certified Wireless USB requires less power than Bluetooth and wifi, but it is not a competent method of managing home devices. ZigBee has a narrow bandwidth as it requires a WPAN network group with low speed.

Wired homes were developed by American hobbyists during the 1960s for the first time [26], but they were restricted because of the technology used in this period. Smart house term was first introduced by the American Association of Homebuilders in 1984 [31,32]. After the introduction of the microcontroller, the cost of control systems decreased quickly, and during the 1990s, there was a rise in the reputation of home automation [33,34]. In spite of attentiveness in home automation, there was no extensive familiarity with these types of systems at the end of the 1990s, but they were still considered the field of the rich or hobbyists in [29]. As there is a large room for improvements and innovations in home automation technology or smart homes, according to ABI research, but till now, 1.5 million smart home systems were deployed in the US in 2012. And in 2017, shipments topping over 8 million could be seen by intelligent interest.

III. IMPLEMENTATION TOOLS

A. Software Implementation Tools

1) Eclipse

Eclipse is an integrated development environment (IDE). It consists of extensible base stations and a plug-in for users' needs. Eclipse generally uses the Java language for the development of applications. Eclipse has Android development tools (ADT) for providing an integrated and powerful environment for Android application development.

2) Arduino IDE

An easy way of writing code and burning it to an Arduino board is provided by the open-source Arduino IDE. It's an open-source physical development platform with a microcontroller board and a development environment for writing software code for the board. Arduino provides the interaction between different objects by taking inputs from switches, sensors and controlling different outputs, including lights, motors, locks, etc.

B. Hardware Implementation Tools

1) Mobile Phone

An Android smartphone is a hardware interface used to run an Android application.

2) GSM Modem

GSM Modem "SIM900A" is a particular type of modem which takes a SIM card and functions when subscribed to by the operator. This allows the computer to communicate over a mobile network when a GSM modem is configured to a computer, through the GSM network. It interacts with the microcontroller through AT (attention) commands.

3) Microcontroller

Microcontroller ATMEGA2560 works as the main program swapping unit, which accepts commands from the GSM Modem and transmits appropriate program data to the relay board for operating the relay either on or off. The microcontroller is programmed using the C++ programming language.

4) Opto coupler

Opto coupler PS2501 is used to provide isolation between 220V and 5V.

5) Diodes

IN4001 diodes are used in this project for configuration.

6) Arduino

Arduino is an open-source physical development platform which contains a microcontroller board and a development environment for writing software code for the board. Arduino provides the interaction between different objects by taking inputs from switches, sensors and controlling different outputs, including lights, motors, locks, etc.

Arduino writes the software in the form of sketches in a text editor. Then, with the extension of .ino, these sketches are saved. The features in the Arduino development environment include cutting, pasting, searching and replacing text. The message block gives feedback after saving and exporting the files, and also displays errors. The console displays text output from the Arduino environment. It displays the complete error message and detailed description. Current board and serial port are displayed on the bottom right and the corner of the window. The toolbar button provides the following options, given with icons.

- Verify: This icon checks the code for errors.
- Upload: This icon is used to compile the code and upload to the Arduino input/output board.
- New: This icon is used to create a new sketch.
- Open: This icon is used to display a menu of all sketches in the sketch book. By clicking one option it opens the sketch in a new window.
- Save: This icon is used to save the sketch.
- Serial Monitor: This icon is used to open the serial monitor.

7) Arduino Libraries

The Arduino code is communicating with the GSM modem using AT commands. The serial commands are sent or received by the microcontroller using the serial communication provided by the Arduino library. The code of the Arduino microcontroller consists of functions like Serial.Begin(), Serial.println(), Serial.available(), Serial.print() and Serial.read(). Serial.begin() is used to initialize the serial port; Serial.available() and Serial.read() functions are used to read data from the serial port.

Table 1 shows the General AT commands used in the Arduino code to control the devices.

Tables 2 & 3 give the list of commands used to operate the devices in different rooms of the house. The device numbering is only for convenience. We can operate any electrical appliance, e.g. TV, fan, Tube light, Bulb, Heater, fridge, etc. and many other electrical appliances.

Table **1**: AT General Commands

AT commands	
AT+CMGF	Select SMS message format
AT+CMGR	Read SMS message
AT+CMGS	Send SMS message
AT+CNMI	New SMS message indications

Table **2**: AT commands for operating Appliances

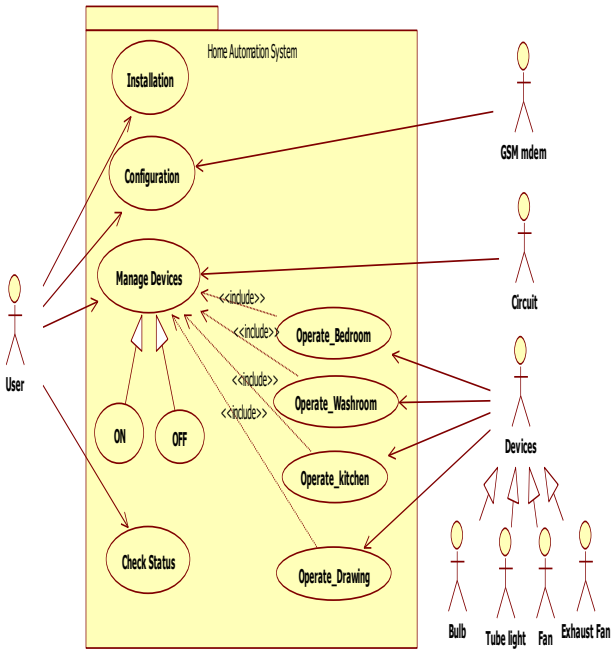
Commands Codes For Operating Devices					
Drawing Room			**Washroom**		
ON		OFF	ON		OFF
Device 1	%@A	%@a	Device 1	%@I	%@i
Device 2	%@B	%@b	Device 2	%@J	%@j
Device 3	%@C	%@c	Device 3	%@K	%@k
Device 4	%@D	%@d	Device 4	%@L	%@l
Bed Room			**Kitchen**		
ON		OFF	ON		OFF
Device 1	%@E	%@e	Device 1	%@M	%@m
Device 2	%@F	%@f	Device 2	%@N	%@n
Device 3	@G	%@g	Device 3	%@O	%@o
Device 4	%@H	%@h	Device 4	%@P	%@p

Table 3: Commands for Status Checking

Commands For Status Checking	
Rooms	**Commands**
Bedroom	%@1
Drawing room	%@2
Kitchen	%@3
Washroom	%@4

IV. UML USE CASE DIAGRAM

A use case is a ladder typically for achieving goal interactions between an actor and a system. The actor can be a user or an external system. Using the system, the user will be able to install the application on his Android phone, configure his application to the circuit for controlling the home appliances, check the status of the appliances in the different sections of his house and manage appliances by turning them on and off.



A Figure 1: Use Case Diagram

V. HARDWARE CONFIGURATION AND IMPLEMENTATION

There are some implementation phases which are discussed below:

i. User sends a message in the form of an ASCII Command by pushing the ON/OFF buttons.
ii. These commands are sent through the GSM network to the GSM modem.
iii. The GSM modem authorizes the user and performs the desired operation.
iv. If the GSM modem is configured by accepting the mobile number, then the user sends the message command for ON or OFF devices.
v. GSM modem accepts command and serially communicates this command to the microcontroller in form of ASCII code. Microcontroller includes a lot of components and registers, etc.
vi. The microcontroller maps the command to the instructions given in the Arduino code.
vii. The microcontroller converts this ASCII code to a hexadecimal code and passes it to the relay drivers. The Relays operate the devices according to the instructions given to them.

Figure 2 shows the whole circuit of the System.

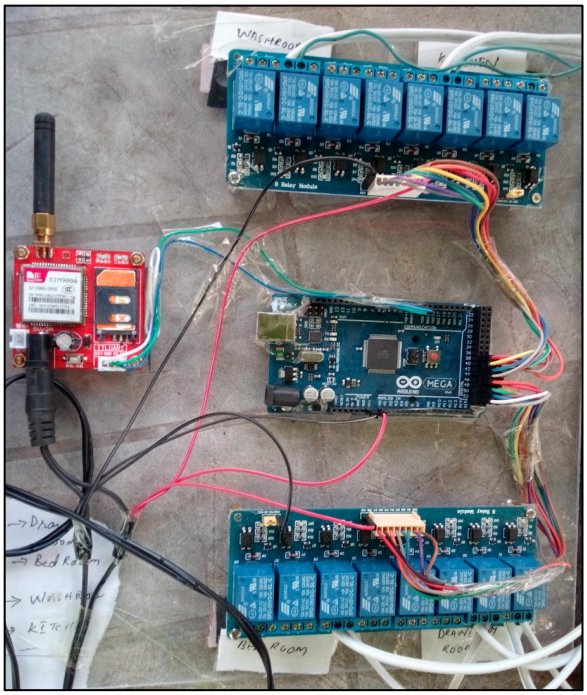


Figure 2: Circuit Diagram

VI. SYSTEM GUI

The first screen of the application is given below. It shows the symbol of a Smart home.

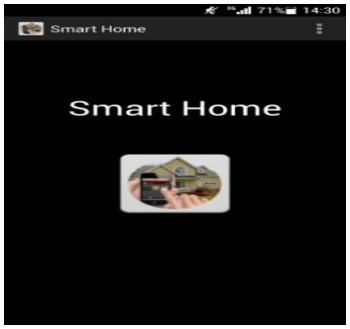


Figure 3: GUI Screen 1

Then the screen of the application opens as given below. It shows the details about the rooms and other parts of the home.

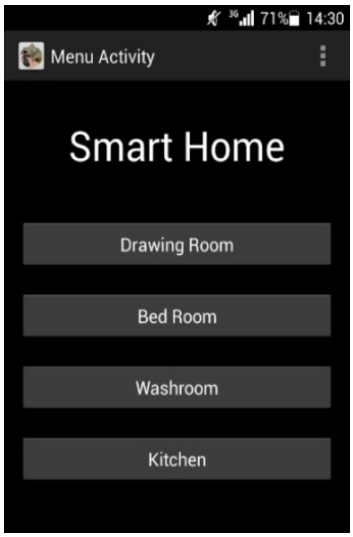


Figure 4: GUI Screen 2

We can choose any room or other option to manage the devices of that portion of the home. If we have clicked on any one option from the Drawing room/Bed room/Washroom or kitchen option, then the following screens will be opened accordingly. If we want to manage the devices, then first of all, we have to enter the number of GSM modems. Click on any option ON or OFF and send a message to the GSM modem.

First of all, the user enters the number of the GSM modem, and then the user can operate the electrical appliances (TV, Fan, Bulb, and Heater) of the Drawing Room by pushing the ON/OFF buttons of the desired appliance. Moreover, the user can check the current status of the electrical appliances in the room by pushing the button "Check Status".

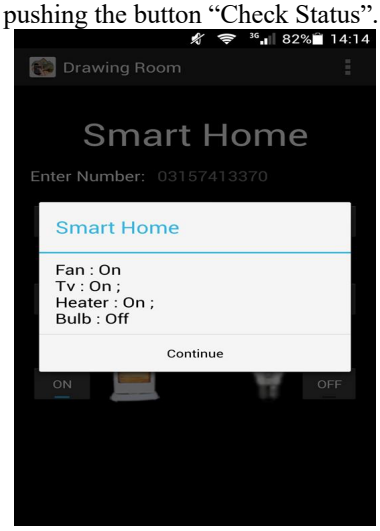


FIGURE 5: GUI Screen 3

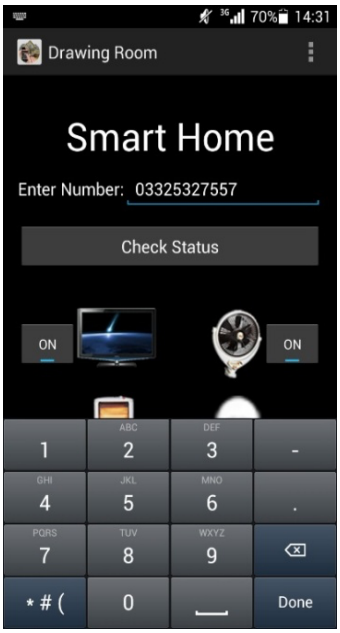


Figure 6: GUI Screen 4

Similarly, the same is the case with other rooms, the user enters the number of the GSM modem and then the user can operate the electrical appliances (TV, Fan, Bulb, and Heater) of the bedroom by pushing the ON/OFF buttons of the desired appliance.

Moreover, the user can check the current status of the electrical appliances in the room by pushing the button "Check Status".

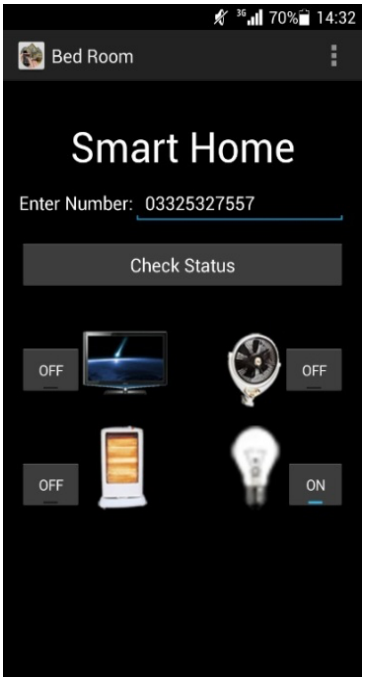


Figure 7: GUI Screen 5

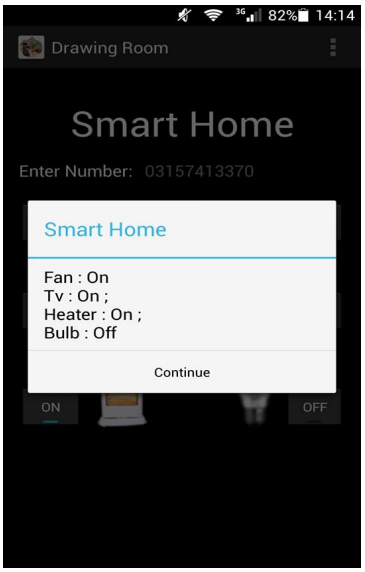


Figure 8: GUI Screen 6

Now, if the user wants to operate the devices of the washroom, then the user enters the number of the GSM modem, and then the user can operate the electrical appliances (Fan, Bulb, and Geezer) of the washroom by pushing the ON/OFF buttons of the desired appliance. Moreover, users can check the current status of the electrical appliances in the washroom by pushing the button "Check Status".

Figure 9: GUI Screen 8

Now, if the user wants to operate the devices in the kitchen, then the user enters the number of the GSM modem, and then the user can operate the electrical appliances (Fridge, FAN, Bulb) in the washroom by pushing the ON/OFF buttons of the desired appliance. Moreover, the user can check the current status of the electrical appliances in the kitchen by pushing the button "Check Status".

Figure 10: GUI Screen 9

VII. CONCLUSION

Home appliances automation framework is developed to provide users with a cost-effective solution for automating home electric appliances from any place in the GSM network. The scope of the system is set according to the accessibility of the GSM network. Although a lot of automation frameworks have been proposed to date, the matter of cost effectiveness and range in terms of accessibility is still a matter to be solved. The purpose was to automate home appliances by using the built-in SMS facility of a smartphone and a GSM Modem. The idea was to utilize the cost-effective nature of SMS these days for controlling home devices and appliances. The proposed automation framework aims at providing a cost-effective, handy control of home electric appliances. The different units (hardware) of the automation framework are discussed in the paper. The smart home application is tested and runs on different Android phones, and the results are quite satisfactory. The allocation is also being tested by a group of users, and their response was encouraging. The home appliances automation framework serves and furnishes a nice paradigm for the future automation framework based on the SMS facility of the GSM network.

VII. RECOMMENDATIONS AND FUTURE WORK

The future of home automation will quickly ride the digital age and will also develop along with networking systems and computers in the years to come. These frameworks aim at providing ease of use

and comfort as the two most desirable parameters of automation and can be extended in terms of reliability, accuracy, cost effectiveness and accessibility.

The proposed home automation framework can be extended in the following ways:

i. The automation framework proposed can be extended with the use of speech for controlling appliances using GSM technology. Instead of selecting, managing the devices, and checking the status by touching the button, the same can be done with speech. This will provide a more attractive and easier use of the application.

ii. The application part can be extended to contain a video monitoring control. The user can monitor the home by making use of the video view provided by the application. Thus, a camera connected in each room and outside will show the view of the home to the user even when he is outside.

iii. It can further be made specific for the elderly and handicapped people who can make effective use of this system at a small cost.

The above-mentioned recommendation and future work can help in paving the way to the widespread development of home appliances automation frameworks in the industry.

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