Design and Modeling of Smart Home with Internet of Things Enabled Automation and Control System

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Abstract

In today's contemporary digital era, the Internet of Things (IoT) is a contentious issue. IoT makes it possible for various devices and physical items to connect to the internet. The virtualization of many types of systems is being implemented in the modern world to enable performance of tasks without direct physical connection. It is simpler to manage several tasks seamlessly without being constrained by distance when high-speed internet and intelligent technologies are used. The tremendous benefits of these innovative technologies necessitate adoption and application of appropriate techniques to address challenges presented by these new applications in the real world. Existing conventional home automation systems are constrained by their high pricing, poor user interface, limited wireless transmission range, and lack of utilisation of IoT technologies. Therefore, this paper presents a proposal for a hybrid (local and remote), effective, low-cost supervisory system for IoT-managed smart home automation. An archetype and an algorithm that allows automated control of home appliances and remote monitoring of home conditions over the Internet is developed. The Proposed model connects several sensors using an ATmega 2560 microcontroller unit as a Wi-Fi-based gateway, enabling the collection and real-time updating of data from the connected sensors. By allowing appliances to operate autonomously, the suggested Internet of Things (IoT)-based system for home automation can facilitate safe and secure living conditions. It is an affordable, dependable automation solution that lowers energy usage and can significantly improve security, safety, and convenience for owners of smart homes.

Keywords: Energy Consumption, Home Automation, Smart Home, Internet of Things (IoT)

I. INTRODUCTION

Due to the widespread adoption of Internet of Things (IoT)-based technologies, smart home applications are pervasive and have grown in popularity. The technological revolution has improved the efficiency, security, and comfort of dwellings. [1]. For users to be able to operate and monitor things at any time and from any location, in recent years, several practitioners have focused on tying everyday items, like appliances, sensors, and actuators, to the Internet. This shift gave rise to the terms IoT and IoE (Internet of Every-thing) and enabled everyday things to become smarter and capable of carrying out difficult tasks. The Web of Objects (WoOs), objects, and other Internet-connected smart devices make up the Internet of Things (IoT), a global network of information for smart homes and smart cities [2]. The lack of intelligent home applications that address several aspects of the home at once, such as automation, security, and safety, as well as reducing energy consumption while consuming less bandwidth, processing power, and cost, makes advancements in smart home technology a necessity [2]. Figure 1 illustrates a smart home environment.

Recently, a number of home automation systems have been presented by various academics and researchers for a variety of applications. While some are utilized as commercial products in markets, others are used to monitor and control home appliances [3–6]. Despite these proposals, home automation is still seen a luxury for the rich and elite. At the close of the 20th century, the development of microcontrollers resulted in a sharp decline in the cost of electronic control and the emergence of home automation. Home automation systems are still seen as the exclusive preserve of wealthy individuals or hobbyists because they are not yet extensively used. Home appliances have been outfitted with the necessary systems for simple monitoring and control using a variety of automation technologies, including remote controls for TVs, fans, air conditioners, and music players [7,8].

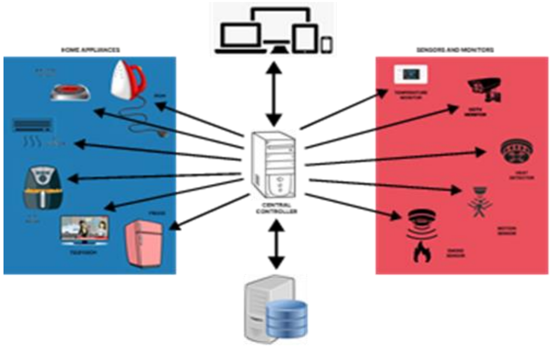

Figure 1: Smart Home Environment illustration.

Utilizing mobile devices with short-range communication protocols, such as Bluetooth and ZigBee [9] and Wi-Fi networks and GSM modules [10], a new era of controlling household appliances has begun due to the rapid progress of information technology. There is no way for people to watch or manage their homes from the outside using any of these systems or technologies, although they are handy for controlling home appliances within. The functionality and communication range of such systems are severely con-strained, even though they can interact with inhibitors to provide ease, Constant energy efficiency, comfort, and safety [1]. Most of these systems don't make advantage of the potent capabilities of the rapidly developing Internet of Things (IoT) technology, which aims to link billions of smart devices (phones, computers, sensors, and actuators) to the Internet.

Most houses today have some degree of "smartness" due to the widespread use of technology with integrated sensors or electronic appliance controllers. Through a control and monitoring access point for home household equipment, devices inside a smart home system can communicate with one an- other and be accessed. For instance, a complete smart home automation system enables monitoring and management of TVs, door locks, cameras, washing machines, and refrigerators. Such a system becomes an Internet of Things (IoT)- based automation system when given Internet connection [11]. The use of home automation systems can reduce energy expenses and electric consumption, among other things. Home automation systems also improve safety and security within the home [12].

Even though technology has advanced greatly, one of the major problems facing the globe today is electricity usage. Information and communication technologies (ICT) alone utilize about 4.7 percent of the world's electricity, and that percentage may rise to 10 percent in the future [6]. Saving energy is therefore the primary issue and the major goal of this initiative. This work have suggested a smart, IoT-based home automation solution to reduce energy use. Thus, the goal of this research is to reduce power consumption (thereby lowering electricity costs) while also ensuring the safety and security of household appliances.

An IoT-based portable smart home automation system's design, fabrication, and validation are presented in this paper. The primary contribution of this study is the creation of an effective, affordable, and portable smart home system that can conveniently operate home appliances and continuously monitor house conditions over the Internet regardless of time or location. The study assumes the following goals and contributions to meet these requirements:

i. Design and construction of a smart home prototype that allows for the monitoring and management of home appliances via an IoT platform and promotes home security by using NodeMCU as a gateway to connect the system to the Internet.
ii. An IoT-based monitoring, control, and automation algorithm for smart homes.

A prototype for a smart home was created using IoT as the foundation. Wi-Fi for local control, Internet of Things for monitoring and control from a distance via an IoT platform, and ubiquity activity evaluation are all part of the suggested solution. Location independence is allowed by this criterion for both mobile service providers and users.

II. RELATED WORKS

Smart home represents a concept rather than actual structure. The idea of home automation has long been present in science fiction, and the American Association of Home Builders first used it to define smart homes in 1984. The voice assistant Smart Home allows you to operate all your home equipment remotely from a distance. Security, ease of use, comfort, and energy conservation can all be enhanced with a smart home. Several researchers have proposed different solutions for smart home automation, safety, security and energy management for human life comfort.

There are numerous fields in which IoT applications can be implemented. IoT has demonstrated enormous contributions made by small scale applications to big scale applications, including those in e-commerce [6,13,14], coal mining [15,16], wearable technology [17,18], smart grid [19,20], laboratory monitoring [21,22], agriculture [23–25], medicine [26] and many other fields [27,28].

Smart home is a setting where various electronic devices are interconnected to offer people smart services. IoT-based smart homes play a significant role in the envisioned and created smart cities all around the world. Smart Homes are created to raise living standards, increase security and safety, and use less energy and resources. Therefore, among the key components of smart homes are real-time monitoring, hacker protection, remote control, and fire and gas alarms [53]. When sensitive and personal data is managed among smart homes, security and privacy solutions must be developed to protect users and company data from theft while maintaining trustworthiness of services [29]. With the rapid advancement of the Internet and communication technology, IoT is generally a recent breakthrough that makes it possible for existing homes to have powerful computer and communication capabilities.

2.1 Home Automation Safety and Security

Numerous methods for improving human lifestyle through home automation safety and security are accessible. Home appliances are monitored and managed via the automation department. Several researchers have implemented a microcontroller-based home automation system. A micro-controller serves as the server for the system, which connects to the Internet through an Android app. In most cases, the Arduino board acts as a server. A cheap microcontroller that is a part of the computer, it can only run one program at once [30, 31]. By combining temperature and current (voltage and ampere) sensors with a home automation system, [32] expands on this strategy. [33] presents a wireless home automation system developed on an Arduino platform. Two modes are offered. A self-automated mode that uses linked sensors to control home appliances automatically and a manually operated mode that uses a smartphone to handle home appliances. The MATLAB-GUI hardware implementation made the system more expensive (needed a PC) and more power-intensive to operate.

Zakariyya *et al*., [34] designed a Bimodal (two-way control) home automation system based on embedded system; Arduino ATmega328 Microcontroller was used. A wireless module called the ESP8266 was set up in the system architecture to work in both online (long-range) and offline (or short-range) modes. The online mode enables remote contact between the user and any home gadgets connected to the Internet. To modify the states of the devices on a cloud server, the user uses an Android application. When making modifications, the Wi-Fi module frequently requests data from the Cloud that has been sent by various sensors connected to the microcontroller. The Home Wi-Fi hotspot may easily provide the Internet connection needed for the Wi- Fi module to send requests to the Cloud. The offline mode is especially helpful when the user is close to the Home Wi- Fi hotspot's range because it doesn't require internet access. However, the system does not keep track of the previous values sent by the Sensors for aggregation and hence makes troubleshooting and maintenance difficult.

Abdulrazaq *et al*., in [35] developed a smart home system for electric appliance monitoring and control. To monitor and manage appliances and stop power wastage, a system based on Arduino and Android devices was created. The Micro-controller, MIKRO-C software, active sensors, and wireless internet services form the foundation of the system design. To activate electrical devices and other appliances in all or a specific part(s) of the home, a microcontroller is used to send a series of coded signals to switches and outlets. When the weather changes, the heater, fan, lighting, and air conditioner are all individually controlled and monitored by the smart home system. The appliance can also be turned ON/OFF using this technique from an Android mobile smartphone. As long as there is a GPRS network, this is possible from anywhere in the world. Three primary elements make up this home management and monitoring system: a micro-Web server, a hardware interface module, and the software package citepiyare2013internet for smart phones. However, the user must use a GPRS connection over an Ethernet shield in order to operate the appliances; as a result, the system becomes unusable when internet connectivity is lost.

Teymourzadeh *et al*., [36] built a GSM-based Smart Home system, with a mobile phone and a GSM modem making up the system's architecture. Timer, Analog to Digital Converter (ADC), and Universal Synchronous Asynchronous Receiver Transmitter (USART) are common components of the 8-bit PIC16F887 microcontroller used in the embedded system architecture (USART). Using an RS232 interface, the GSM modem provides text commands to the PIC microcontroller. In Shinde et al. [37] the signals sent by the IR remote, Bluetooth, and GSM are decoded by the microcontroller, which then sends the appropriate control signal to the relay module. Electrical appliances are controlled by clicking on an Android application; from a smart phone, commands are delivered to an Arduino through an IR receiver (TSOP 1738), a GSM module, and Bluetooth module. The Arduino then turns the specified appliance ON or OFF. However, this system was not intended to provide both home security and appliance monitoring.

Wadhwani *et al*., [38] designed an automatic control Smart Home system using wireless technology ESP8266 module. Wi-Fi module, integrated sensors, and appliances are all connected to an Arduino UNO microcontroller. By activating one or more relay switches from the microcontroller, readings from the sensors cause changes in the status of the appliances. A device is controlled by a flex sensor based on finger bend motions that are recognized. The opening and closing of the door are managed by the accelerometer. If the door lock brakes, the magnetic sensor notifies the user. The user gets informed if there is a fire in the house by the flame sensor. The user can view the state of the appliances on his laptop and smartphone by connecting to the web server, and the status of the appliances is uploaded to the cloud platform. The Microcontroller performs the control of appliances based on value transmitted by sensors. In Santoso and Vun [39], the initial configuration of the system is carried out using a Wi-Fi gateway as the system's central node. In addition to giving the user a way to configure, access, and monitor the system through an Android-based device running the necessary ap-plication program, it is also responsible for authenticating the communication between IoT devices. However, in order to manage and update the status of the home appliances, this system needs internet connectivity.

Asadullah *et al*., [40] implemented a design based on Bluetooth communication technology for a Home Auto- mated system on an Arduino board. The design's fundamental elements included a Bluetooth module, sensors, and a smartphone application. The Bluetooth module HC-06 was interfaced with an Arduino board, and home appliances are connected to the Arduino board via a switching relay. For serial communication between the Bluetooth module and the smartphone, which is additionally interfaced with the Arduino board, a smartphone application was employed. The system offers both remote control and monitoring of appliance. There are two (2) main parts in the design i.e., the Hardware and Software. The hardware part integrates the Bluetooth module to the Arduino board and then to the home appliance through a relay switch. The software used for the design was an Arduino

IDE, and A Smartphone application named Bluetooth (BT) Simple terminal was used for wireless communication between Smartphone's and Arduino board. This general-purpose home automation system was design to control up to 18 devices including sensor for monitoring the environment condition. The design was invariably functional when operated within the Bluetooth range, and its design enables wide appliance remote control and monitoring. Nevertheless, the control and monitoring of home appliances fails outside the Bluetooth range. Thus, the design cannot function from a distance outside the house.

In addition to home automation, safety and security are other important aspects of a smart house, and various re- searchers have demonstrated their value in this area. ZigBee- based home automation and security system with multi- home communication capabilities is shown in [41]. On the other hand, the user can command household appliances by sending an SMS to the main controller. Jan et al. [42] proposed a home safety and security system that uses gas and flame detection methods as well as geriatric fall detection to safeguard the older population from potential dangers. The passive infrared sensor (PIR) and Arduino-based security system for smart houses is proposed in [41]. The authors of this study used an Arduino and PIR for motion detection, and combined camera sensors and PIR for intruder detection. The camera sensors will turn on to take pictures when the PIR sensor picks up motion. Additionally, they extracted key features from the collected image using a histogram of gradient (HoG), and these data were then fed into a support vector machine (SVM) to detect intruders. The system activates the alarm to notify the homeowner of any action if the intruder is found. Their method achieved an accuracy of 89 percent for intruder detection, and the trial findings showed that it only takes two seconds to detect motion. The system frequently misclassified activity and raised an alarm for routine activity. By utilizing contemporary procedures, the precision in this instance has space for improvement.

Fog computing technology is used by the authors of [43] to assess foot size, pressure, and movement in real time for person identification. For intruder detection, an adaptive neuro-fuzzy inference system (ANFIS) based on predictive learning is employed. Additionally, they raised an alarm using this method in case of any emergency in real-time scenarios. Their work is verified in a smart home environment database that was chosen from the UCI, a 49,695-record online database. It includes identity-based factors, foot size, pressure—specifically, weight—and movement. Their suggested work outperforms other SoTA prediction models in terms of performance. A method for spotting flames, a person falling to the ground, and the release of any dangerous gases was suggested by Jan et al. in their paper [42]. With an RPI-based prototype that can be readily fastened to old individuals as a safety device, this system is designed with them in mind. The system oversees notifying their family members of any emergency along with their whereabouts using the global positioning system (GPS).

2.2 Energy Consumption Monitoring

A crucial component of the smart home is monitoring and decrease of energy expenses, in addition to automation, safety, and security. The amount of energy used for residential purposes is rising daily. A distinct smart home module, such as automatic lighting control that considers the amount of natural light, has been introduced for this purpose. The use of daylight instead of automatic electricity consumption limits in business buildings via light sensors has been suggested in several research studies. As a result, there are several strategies available to reduce household energy use [44– 47]. ICT, sensors, and network capabilities are all part of smart home technologies, which enable voice, touch, or ICT-based smartphone applications to automatically switch between home appliances. Better opportunities for users to effectively manage and control their home electricity are provided by smart meters and other devices. In [48] to track the energy use of lighting and residential appliances, ZigBee-based energy measurement modules are employed. The household appliances are controlled, and the energy generation of renewable energies is monitored using an ARM9- based renewable energy gateway.

2.3 Smart Home Automation Platforms

The network plays a significant role in connectivity of smart things. Smart objects are made up of controllers, sensors, actuators, and other processors that are utilized for network communication, network control, and network monitoring [49]. Although cloud computing is used in smart homes, there are several significant drawbacks, such as latency and reaction time. A method to get around the restrictions of cloud computing was put forth by Li *et al*., in [50] in light of this. The decision to switch from cloud to fog computing was made after the authors looked into the data latency and response time problems with smart objects (used in smart homes and smart cities) in cloud computing. This enabled the smart object to interact in real-time while overcoming latency and data volume and speed issues.

Another problem with cloud computing is scalability, as described in [2]. A better approach to energy management is provided by fog computing. With customized control-as-a-service, the fog computing paradigm's adaptability, scalability, and open-source hardware and software enable the user to cut implementation costs, times, and energy usage. Resource wasting problems in cloud computing and network storage were investigated in [51]. A survey of some recent home automation platforms and their comparison can be found in [52].

III. DEVELOPMENT OF PROPOSED IOT SMART HOME

3.1 Proposed Framework

A variety of microcontrollers and processors, including Desktop PC, RPI, Arduino, and others, can be used to integrate developing technology in the areas of home automation, security, safety, and energy consumption. All these microcontrollers and processors have advantages and dis- advantages, but because to its distinctive qualities, Arduino ATMega 2560 is the one that is more effective than other devices. The block diagram of the proposed Smart Home control and Monitoring system is shown in Figure 2.

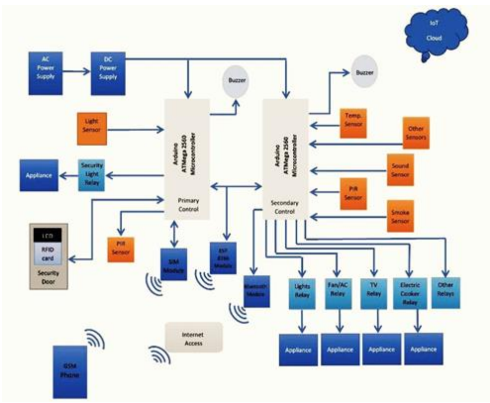

Figure 2: Proposed Block Diagram for Smart Home Monitoring and Control System.

The block diagram illustrates the big picture of the pro- posed system.

The general control and power flow of the functioning design consisting of Arduino ATmega2560 Micro- controllers, communicating modules, Sensors, Actuators and Appliances are represented by the arrows. The two micro- controllers, the Sensor Modules, Actuators, power appliance and display modules are powered from the regulation of 220Vac to 12Vdc, 9Vdc and 5Vdc respectively depending on the voltage rating of the digital devices. The micro-controller operates on the basics of Primary and secondary processing. Digital and analog signals from the sensors are fed into the ATmega2560 Micro-controllers from which the general home automation is enabled after processing these signals. The Automation process of the system is based on the Sensor status, remote control and wireless control. Appliance are operated through the switching of relay actuators as signaled by the micro-controller. The Sensor base appliance control is dependent on the environmental condition and the sensitivity of the sensor.

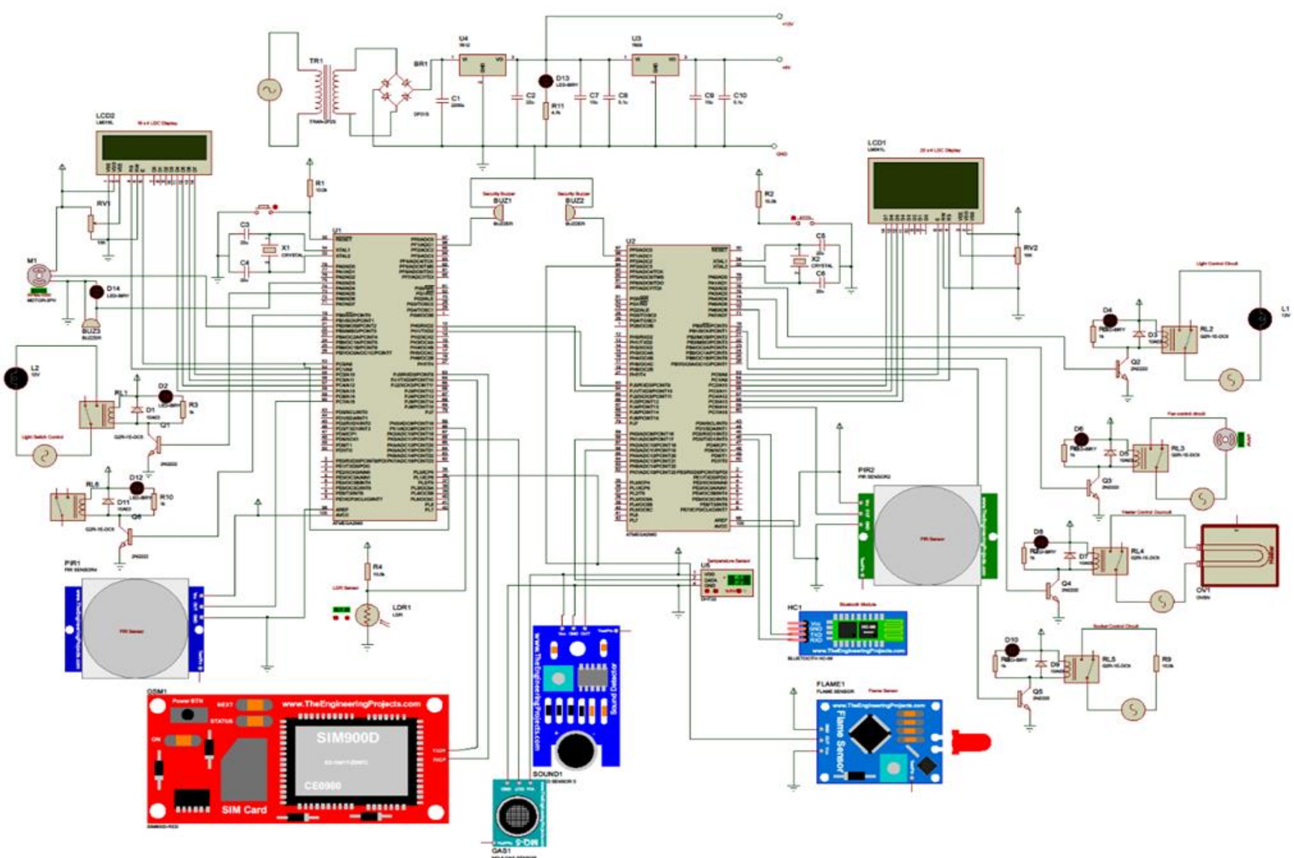

Figure 3: Proposed Circuit Diagram for Smart Home Monitoring and Control System.

The Bluetooth control of home appliance is based on the Smartphone Bluetooth application which is transmitted into the micro-controller though the Bluetooth module, while the wireless control and monitoring is based on the Cloud base database that is accessed using a dedicated URL from any secure wireless network access which communicates with the smart home through the Wireless module (ESP 8266). The circuit diagram of the proposed system as visualised in Proteus design and simulation environment is presented in Figure 3.

3.2 Smart Home Prototype Construction

The structure of prototype was designed on Revit environment. The Smart Home prototype was then crafted using Straw board material because of its availability, affordability, and durability. The plain straw board was cut and partitioned to dimension of floor plan, and the same was used to serve as walls for the prototype, where it was cut to form the walls of the prototype as dimensioned on the model. The whole structure was fastened using hot glue with the aid of a glue gun. The prototype model is a single bedroom, Living room, a Kitchen, Dinning space, Toilet and a corridor. A Medium- density fiberboard (MBF) wood of 5mm thickness was used as the base structure which gives the whole structure firmness after gluing the prototype to it. Doors and windows holes were curved from the straw board as modeled with ease to allow installation. The Doors and Windows were made from smoothly cut MBF wood with metal hinges to allow swing and facilitate the lock mechanism on the Doors. The skeletal framework for prototype is presented in Figure 4.

Figure 4: Smart home fabrication Processes.

Electrical appliances which include light bulbs, electric fan, electric switches, and wall socket were installed within the prototype. Connections to the relay control using a 5mm dual core copper wire, digital sensors and actuators were also installed on the internal walls and connected using a CAT 6 cable strands for power and signal after which wallpaper was used to cover the exterior walls of the prototype to enhance appearance and neatness. LCD modules were installed at the entrance and bedroom for display, control and monitoring of appliances. A pattress box was used to house the power pack, relay switch, communication module and micro-controller that facilitates the monitoring and control of smart home appliances. A detachable roof was also fabricated using the straw board material to give the prototype structure a look this was placed to give the structure a look of completed building. The completed structure consisting of the appliance, sensor, actuators and control system works smartly in automation and wireless communication mode. The completed model is presented in Figure 5.

Figure 5: Completed smart home model.

An AC supply of 220Vac was regulated to 12Vdc, 9Vdc and 5Vdc respectively from a set of discrete Electrical and electronic components consisting of a Step-down transformer, Diodes, Capacitors, and Regulators for the DC circuit. Two Arduino ATMega 2560 Microcontrollers (Primary and Secondary controller) are used for the design to ensure Fast communication, processing, memory, and data communication. Sensors (Temperature and Humidity Sensor, Pyroelectric Infrared Sensor, Light dependent Resistor Sensor, Smoke Sensor, Sound Sensor, Flame sensor) are connected to the Microcontrollers these sensors send various data to the microcontrollers for aggregation and monitoring. Relays switching circuit of 5V and 12V consisting of NPN- transistor, LED, Resistors and Diode are used to perform the switching of appliance depending on the appliance power capacity. The Microcontroller through the Relay switch and sensors configuration, controls the electric appliances (Fan, Security light, Socket outlets, Gas cooker, Television etc.) which operates on AC source, 5V or 12V through Automatic, direct switching or Pulse Width Modulation (PWM) control. An RFID module configured with the Security Door grant access only to the authorized user when the right key is swiped, a Magnetic lock deject to open the door. On the Security Door is a (16x2) Liquid Crystal Display which can be used to display message to guest when user is out of reach. ESP8266 wireless module was interfaced with the Microcontrollers to enable Internet access reaching the cloud base server for remote control and monitoring over short and long distance.

A Bluetooth module is also interfaced with the secondary controller for short distance remote control in the absence of Internet connection. A SIM900L module is interfaced with the Primary controller which is configured to send SMS to the user in times of any unusual situation like Gas leakage detection or Security Door Bridge alternatively, Buzzers are installed to alarm when there is any abnormal activity. A (20x4) LCD display is also placed in the control system to identify appliance state for home user in the offline mode. A cloud base server is designed to view and keep records of the home state specifying the Temperature as well as Gas leakage value, other sensor values and general appliances which are ON/OFF, and these appliances can also be controlled using the Web control Buttons. This cloud base server can be accessed using a Smart Phone or a PC with the right URL address. The flowchart of the proposed system operation mechanism is presented in Figure 6.

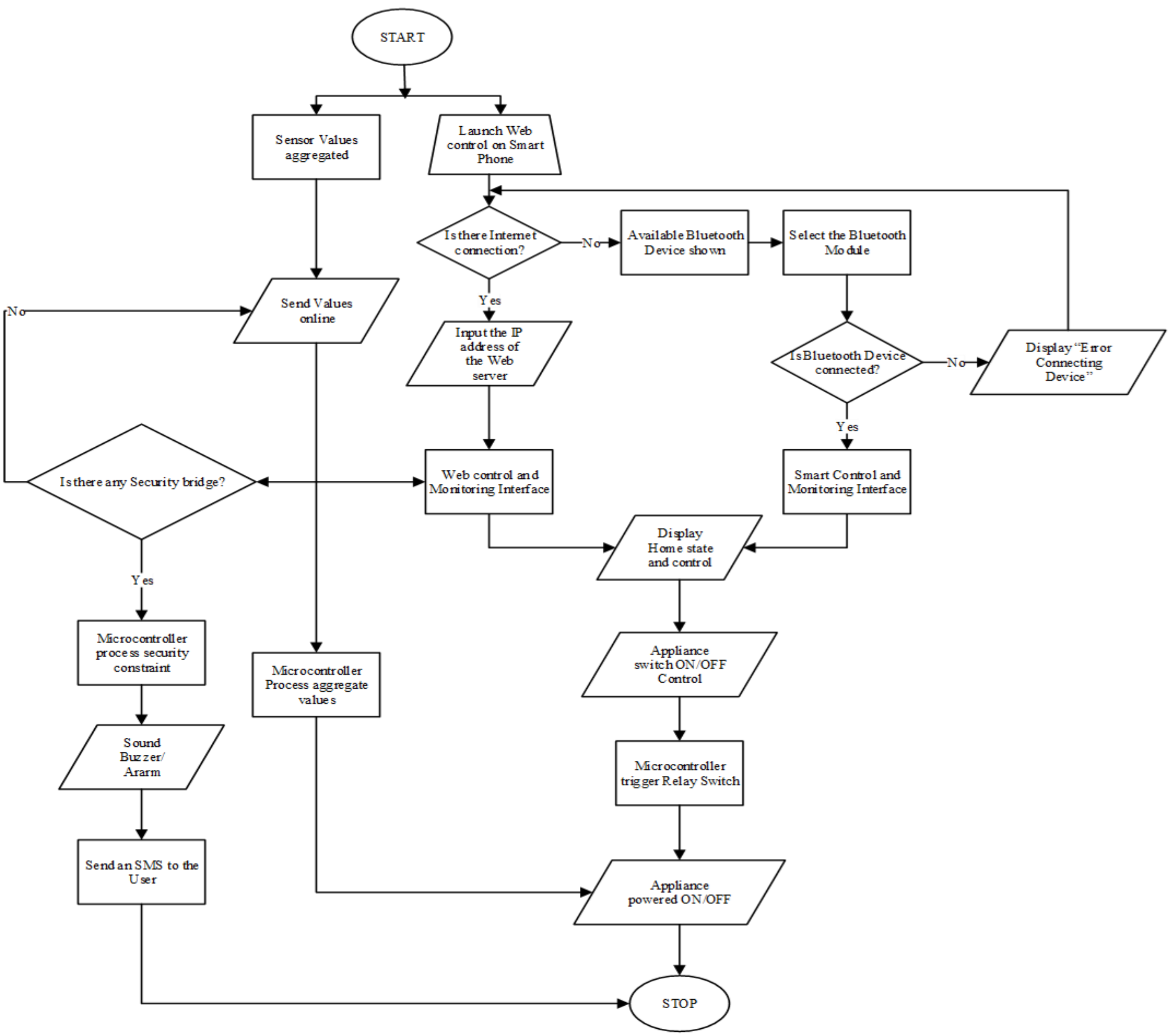

Figure 6: Proposed flowchart for smart home system operation mechanism.

IV. Experimental Results and Validation

This section presents results to confirm operability of the proposed smart home system prototype. The system performs control of home appliance (Security Door, Electric bulb, Electric Fan, Electric Sockets, and others) as well as monitoring various conditions/home states such as motion, Light, Temperature and Humidity, Gas and Smoke levels from their respective sensor modules via a Liquid Crystal Display (LCD) placed inside the house and a dedicated web page on a free host (www.000webhost.com and myphpad- min.net) through a Smart Phone or Laptop. A user can control home appliance and monitor home state anytime anywhere when connected to an internet service. The most important advantage of this implementation is the application of IoT to utilize monitoring and control of our environment with ease and Power energy minimization by appliance. Users have choice for multiple control and monitoring option by logging onto the user interface from any device connected to the internet. The Sensor automation is a benefit that helps physically disabled to navigate and control appliance without contact.

ESP8266 module is the main component for online communication in the SH; the module provides continuous inter- net connectivity to the SH control system. Home user can use either a Smart Phone or a Laptop connected to an internet to access user interface on a web page through a URL on the host domain. The web page contains control button of home appliance on the top panels of the interface. Sensor reading of Temperature, Smoke and Gas in the house are monitored in the form of numeric values from 0to100 for temperature reading and 1to1024 for smoke and gas reading. When sensor data are read, they are uploaded to the database which is then viewed through the webpage. Similarly, when online control is initiated, the values are stored in the myphpadmin.net; upon refresh of the page the data uploaded would be viewed and the downloaded data would initiate control action.

The BT05 module is a short distance Bluetooth range that allows up to 10m connectivity. This module together with an android mobile application created on MIT app Inventor, is used to control appliance by simply pairing the Bluetooth module to the Smartphone which contains the SH appliance control. Appliances are ON and OFF with a touch of the virtual ON and OFF on the screen. Home appliances are controlled within a distance range of 10m, upon testing close distance initiate quick response of appliance control while distances greater than 7m offers slower response. The use of Bluetooth as an alternative control system is essential when there is no Internet connectivity for online control. Manual switches are installed to compliment the Bluetooth control.

The beauty of the monitoring and control sensors in the SH is not just to sense the user or intruder within the SH but to also initiate certain action. The Light Dependent Resistor (LDR) controls the security light around the SH when it is dark. The sensor is calibrated to switch ON the security light when the sensor reading is 450 and turns it OFF when it's below that. The Motion sensors switches ON the Lights at within the SH when it reads a (1) value indicating the presence of human and the light goes OFF when the sensor reads (0). The sound sensor is also used to switch on Light in the room and toilet as it was configured to switch when there is two consecutive claps. The toilet is configured with a magnetic switch to turn the light OFF when the door is open. The temperature sensor controls the ceiling fan to ON when the temperature of the SH is greater or equal to 270C and the fan stops when it's below.

GSM Module was integrated with the security functions of the buzzer to send SMS with the sensor readings of the SH when it's above the normal. When the Flame sensor records flame at a distance within the house it directly dials the home user line for emergency. When the temperature sensor records a value greater than 500C in the kitchen, it sends an SMS to notify the user of the danger of explosion; the same SMS is sent when the Gas sensor records a value greater than 450 this notification is accompanied with a buzzer within the house. Notification messages are sent when the smoke sensor records a value greater than 450. The configuration of the monitoring and control of the SH was effectively done and was tested against artificial values by triggering the sensors; it was obvious that both the control and monitoring of appliance was effective and working properly. The only issue it when there is a poor network connectivity which takes long to connect and communicate values to and from the SH. An illustration of the user interface using a smart phone via Bluetooth and the web page screen display for monitoring and control are presented in Figures 7 and Figure 8 respectively.

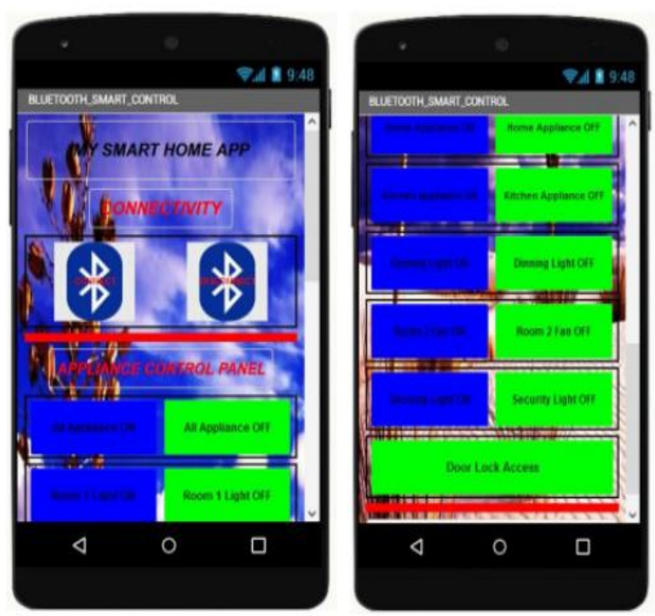

Figure 7: Bluetooth control interface using android smartphone.

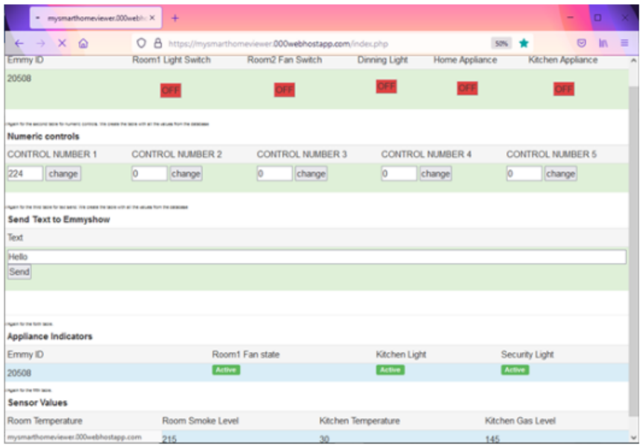

Figure 8: Bluetooth control interface using android smartphone.

4.1 Appliance Control Test Results

The response time for appliance using sensor and Bluetooth switching methods were recorded at different distances. This is to identify the best switching option at different distances. Table 1 presents appliance response time using sensor switching method.

TABLE 1
APPLIANCE RESPONSE TIME USING SENSOR SWITCHING.

Sensor Switch (N)	Time Response (ms)
1	100
2	200
3	150
4	200
5	400
6	200
7	100
8	250
9	200
10	200

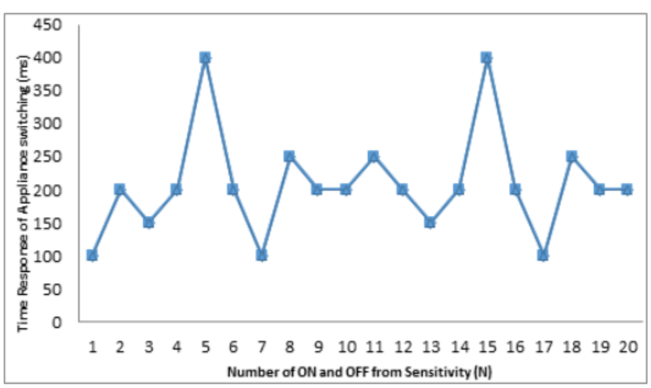

Figure 9. Appliance time response based on number of ON and OFF.

Figure 9 presents the plot of switching method sensitivity and appliance response time. Table 2 presents switching method appliance response with time. The plot of appliance switching using Bluetooth is presented in Figure 10. Furthermore, the response of appliance with respect to distance using Bluetooth was also tested and plotted. This is to measure the coverage distance for control. Table 3 presents the results of Bluetooth response over distance. The plot of Bluetooth response with distance is presented in Figure 11. The plot indicates the response time of switching increases with increase in distance.

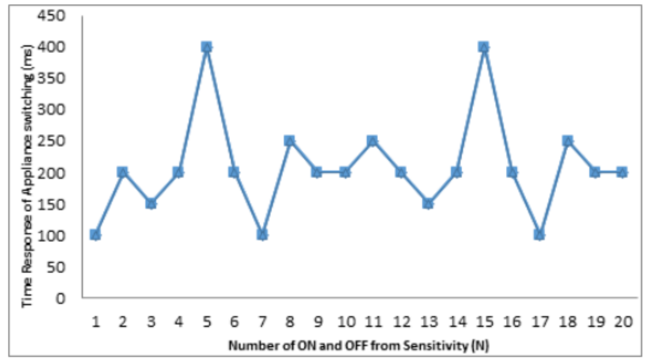

Figure 10: Appliance response using Bluetooth method.

TABLE 2
APPLIANCE RESPONSE TIME USING BLUETOOTH SWITCHING.

Sensor Switch h(N)	Time Response (ms)
1	300
2	400
3	300
4	350
5	300
6	150
7	350
8	340
9	200
10	100

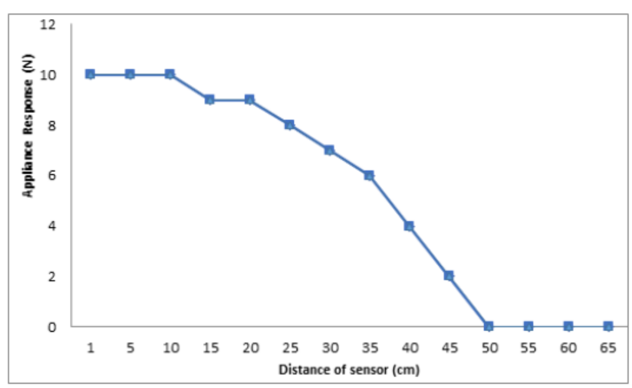

Figure 11. Appliance time response using switching method.

TABLE 3
BLUETOOTH APPLIANCE RESPONSE TIME WITH DISTANCE

Distance (cm)	Appliance Response (N)
1	10
5	10
10	10
15	9
20	9
25	8
30	7
35	6
40	4
45	2
50	0
55	0
60	0
65	0

V. CONCLUSION

In this study, an IoT-based portable, user-friendly, and cost-effective automation system for smart homes was created. The created smart house system can be easily installed in a real home to enable real-time monitoring of home conditions and management of home equipment. The proposed system can be expanded by including more sensors and actuators. To make the produced system appropriate for future commercialization, it can also be upgraded. The control box was powered by solar panels in our subsequent study rather than using batteries to make the suggested system more environmentally and energy friendly. Printed circuit boards will be utilised to optimise every circuit while saving space and lowering the risk of connection losses or short circuits. PV power systems will be implemented in future projects to increase conservation even more and prevent control malfunctions.

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