A Low Cost Home Automation System Using Wi-Fi Based Wireless Sensor Network Incorporating Internet of Things(IoT)

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***Abstract*— With the rapid increase in usage and reliance on the vivid features of smart devices, the need for interconnecting them is genuine. Many existing systems have ventured into the sphere of Home Automation but have apparently failed to provide cost-effective solutions for the same. This paper illustrates a methodology to provide a low cost Home Automation System (HAS) using Wireless Fidelity (Wi-Fi).This crystallizes the concept of internetworking of smart devices. A Wi-Fi based Wireless Sensor Network(WSN) is designed for the purpose of monitoring and controlling environmental, safety and electrical parameters of a smart interconnected home. The user can exercise seamless control over the devices in a smart home via the Android application based Graphical User Interface (GUI) on a smartphone. The overall cost of large scale implementation of this system is about INR 6000 or USD 100.**

Keywords— Home Automation System, Wireless Fidelity ,IoT,Wireless Sensor Network,Android.

I. INTRODUCTION

Presently, due to the proliferation of smart devices and the ever increasing dependence on their affluent attributes, it becomes an indispensable necessity to interlink multiple smart devices. The Wireless Fidelity (Wi-Fi) technology provides an excellent medium through which multiple devices can be connected to one network. Wi-Fi operates over an internationally approved frequency band of 2.4GHz. This paper explores the numerous possibilities of interlinking these smart devices while making judicious use of Wi-Fi technology.

The benefit of this inter-linkage is the concurrent monitoring and controlling of smart devices. 'Home Automation' is a concept which involves real time control and monitoring of multiple domestic appliances. Home automation can be defined in myriad ways; the author in [1] portrays home automation as a methodology to enhance the quality of life of people with the introduction of technology in the household. According to the author, the oldest standard for the communication between electronic devices was the X10 industry standard, developed as far back as 1975. This standard utilized the existing electrical power lines, which provided limited control over the home appliances.[2-4] incorporate various wireless communication protocols viz. Bluetooth, ZigBee etc. However, this does not assuage the intrusiveness caused due to the use of wired communication. These systems also use expensive sensors and relays which are intrusive and the whole circuitry becomes cumbersome. There is a paucity of security in such designs.

This paper explores a novel methodology for the automation of home appliances by exploiting their ability to be interlinked. The experimental rig involves the use of a ESP8266 Wi-Fi module, Atmel ATmega microcontrollers (µCs), nrf24101+ RF modules, sensors ,SPDT relays and solid state relays(TRIAC) for voltage regulation. Each µC is provided with a RF module for the purpose of communication with other µCs. One of the µCs is configured as a 'Hub' or 'Gateway' and the remaining µCs are configured as sensor nodes [5-7]. Tree network topology is used in the present work [8-9]. The µCs are programmed to perform specific tasks such as, reading sensor values, controlling relays and sounding alarms. All the sensor readings will be communicated to the 'Gateway' from the nodes via the RF modules. The data received at the Gateway is sent through the UART serial port to the Wi-Fi module [10-12]. The Wi-Fi module sends data to the server where it is stored and can be retrieved for future use. The user is provided with an android application based Graphic User Interface (GUI) to exercise the desired control over the lights, fan speed regulation, control of appliances, and information regarding the temperature, humidity, water tank level or rain. The additional benefits of this methodology are its security features which include fire alarms, motion detection, and gas leakage detection. Mobile commands will be published to the Message Queuing Telemetry Transport (MQTT) server which is accessed by the user on the smartphone via the android application [13-15]. The overall cost of mass implementation of this technology is expected to be less than INR 6000 or USD 100 (Excluding the cost of Android smartphone). Fig. 1 shows the proposed block diagram of the Home Automation System.

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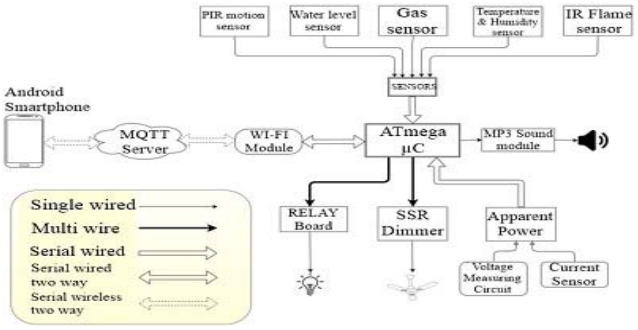


Fig. 1. Block Diagram of the Home Automation System

II. SYSTEM HARDWARE

The primary objective of this methodology is to provide a low cost Home Automation System (HAS). The choice of hardware elements in devising the system is the key in fixing its overall cost .The HAS consists of a Wi-Fi based Wireless Sensor Network(WSN) with a central 'gateway' or 'hub' acting as the data coordination sensor node between the sensors employed and the web server. It houses the ESP8266 Wi-Fi module connected to the web server with a designated IP address[16-21].The intranet communication between the sensor nodes and the central hub is facilitated by the nRF24101+ RF module operating on the Tree Network topology. Fig. 2 elucidates the interconnection of the gateway with the sensor nodes in the present WSN.

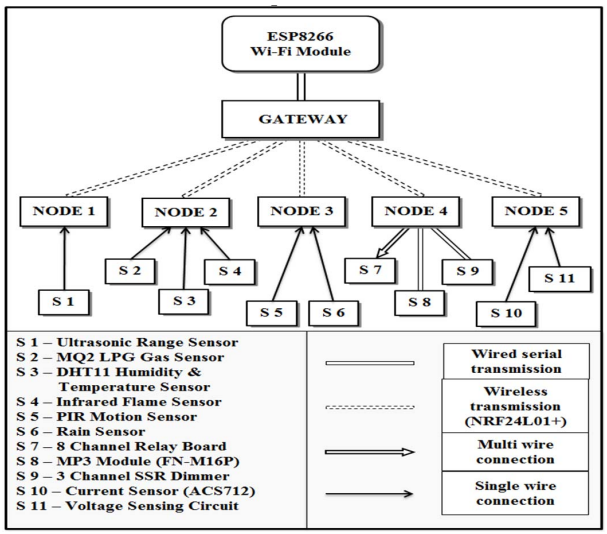


Fig. 2. Organisation of nodes in WSN.

In the present work,five sensor nodes are created. Each of these nodes consist of a legion of sensors and other associated paraphernalia as shown in Fig. 2.One among these nodes is provided with the security alarm in accordance with the acoustics of the home in which the HAS is installed.The parameters measured by the sensor are communicated to the nearby µC and then to the web server. An Android application is developed which can access the server database. The user is accordingly informed or warned in case of an emergency by means of an alarm.Also,a caution message is displayed in the smartphone's mobile application.Different sections of the HAS are:

A. Temperature and humidity sensing:

A DHT11 temperature and humidity sensor is used to obtain the real time status report of the temperature and humidity levels. This sensor contains a humidity measurement component and a Negative Temperature Coefficient (NTC) based thermistor for temperature measurement. The humidity measurement component consists of a moisture holding substrate to identify the changes in humidity. The NTC thermistor operates on the principle of variable resistance which is facilitated by the use of semiconducting materials to identify the changes in temperature.

B. Gas Leakage warning system:

Gas leakage is detected by the MQ2 gas sensor which is sensitive to a certain inflammable gases. In the event of a gas leakage, there is a notable change in the sensor's electrical conductivity which forms an analog input to the respective µC. This change in conductivity is identified by the sensor.

C. Fire alarm system:

A flame sensor LM393 with an infrared (IR) based NPN phototransistor (sensitive to the light sources of 760nm-1100nm analogous to the heat emitted in an event of fire) is used.

D. Burglar alarm system:

A Passive Infrared (PIR) sensor HC-SR501 is used to identify the presence of objects in its line of sight which can be used as a warning system to detect unauthorised trespassing in homes.

E. Rain Sensing:

A M009 raindrop sensor which identifies the incidence of rain droplets on its surface by forming a closed conducting path is used. It provides a digital output to the neighbouring µC confirming a wet atmosphere.

F. Switching and Regulation of loads:

An eight channel relay board and a three channel Solid State Relay (SSR) dimmer are used for switching and regulation of loads respectively. The relay board consists of 8 Single Pole Double Throw (SPDT) relays which is used for switching on and off the devices connected to it. The regulation of the device parameters is done by the SSR dimmer assembly via the onboard TRIAC and PIC µC. The firing angle of TRIAC is varied by the PIC µC to perform the desired voltage regulation of the connected devices. An opto-coupler is used for providing isolation between the TRIAC and PIC µC.

G. Voltage and Current sensing:

The voltage measurement is done by using a step-down transformer coupled with a voltage divider circuit. The output of this circuit is conditioned with an RC network to the desired measurable voltage level as shown in Fig. 3.

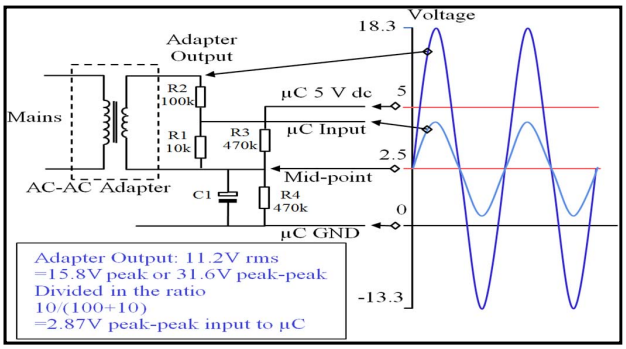
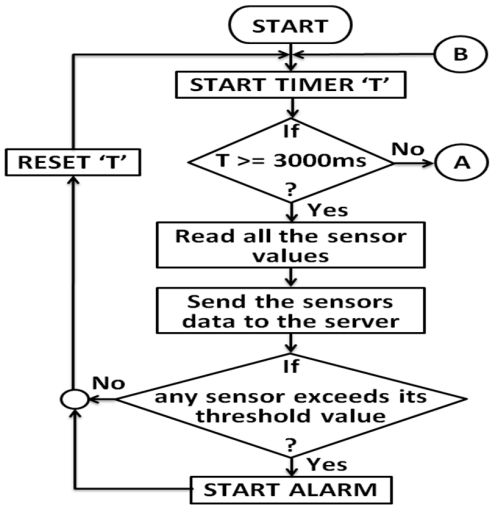


Fig. 3. Voltage Measurement Circuit

The current sensing is done by the Hall Effect based ACS-712 current sensor. This sensor consists of an onboard Hall Effect transducer which generates an equivalent analog voltage output. Mathematical conversions in programming is done post analog to digital conversion by the µC to display the current measurements. Hence, the apparent power in VA can also be obtained.

III. Hardware Programming and Apllication Development

Every system consists of requisite programming to enhance the flexibility and to accordingly entail the promoted traits of compactness and low cost implementation of the HAS. In the proposed system, the software design platforms used are ATmega IDE, ESPlorer and Android Studio. The designed WSN permits the collection of data from various sensors. The simultaneous validation of the limits of each class of data such as temperature and humidity is accomplished by programming the hardware components of WSN. The provision for programming the μC is provided by the ATmega IDE comprising the editor, feedback space and a console for the display of errors and serial data. The acquired data is sent to the user over the internet using the concept of IoT.The flowchart of the system software implementation is as shown Fig. 4.



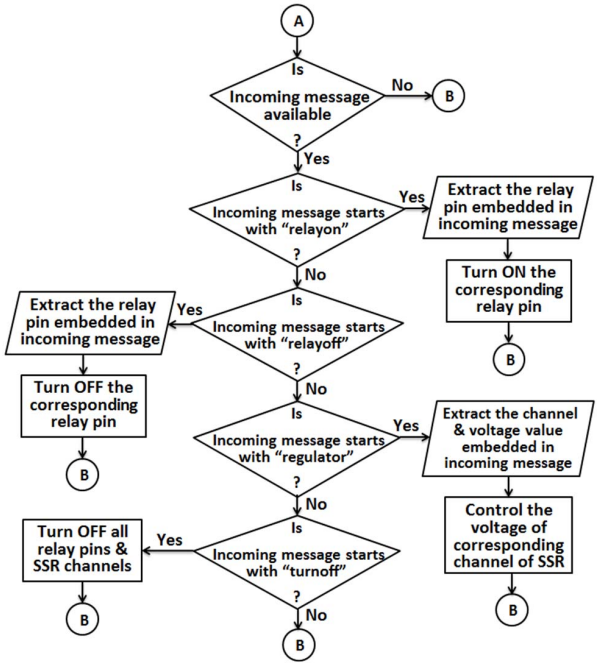


Fig. 4. Flowchart of software implementation.

ESPlorer software package is employed to program the ESP8266 Wi-Fi module to communicate with the MQTT server. Finally, the control to the user for the prospect of safety and monitoring of the devices is accommodated by designing an android application employing Android Studio. The coding of the Android Studio is based on Java. The Android Studio is recognized for its built-in cloud support which abates the integration of messaging and application engine. Hence, the user has the privilege of assessment and control of the fully automated home via the state-of-the-art GUI provided on the Android smartphone.

IV. Graphic User Interface

The primary requirement of HAS to monitor and control multitudinal devices is accomplished using a Smartphone application. The application is developed using Android Studio based on JAVA platform and User Interface of those are exemplified. The application comprises of distinctive tabs to:

- Supervise the diverse set of sensors by considering the values divulged on the display screen.
- Control the activities of devices such as Lights and fans.
- Asserts the security of the system.

The designed android application provides discrete display screens viz., History, Security, Lights, Regulator and Sensors in order to achieve the antecedent operations.

The datalog and the entire details of communication between the system and the user is located in the History tab. The preceding activities and essential information stored in the server can be retrieved and delineated on this user-friendly screen.

The HAS encloses assorted sensors measuring environmental, safety and electrical parameters as shown in Fig.5. Temperature, humidity and rain sensors embed in the environmental factors category, sensors used for detection of fire, gas, water level and motion are placed under the safety parameters while the voltage, current and power measuring sensors fall under the final category. Power is computed in terms of VA for user reference. The real time readings of these sensors are deciphered and displayed that notifies the user to formulate the action plan in times of emergency.

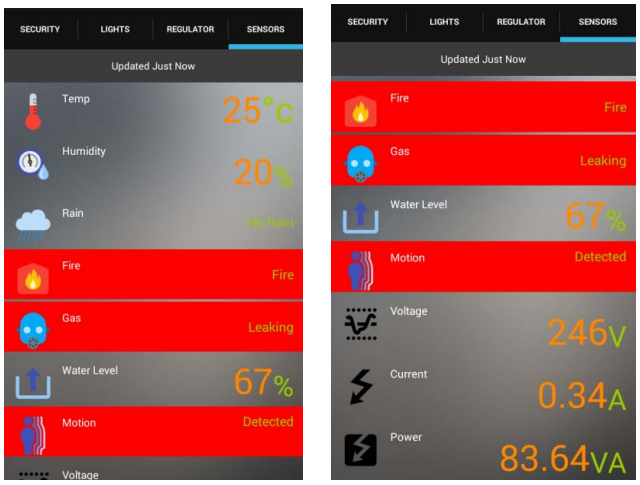


Fig. 5. Application window showing the information console.

To enhance and ameliorate the system flexibility, lighting optimization and fan speed regulation privileges are accessible as shown in Fig.6

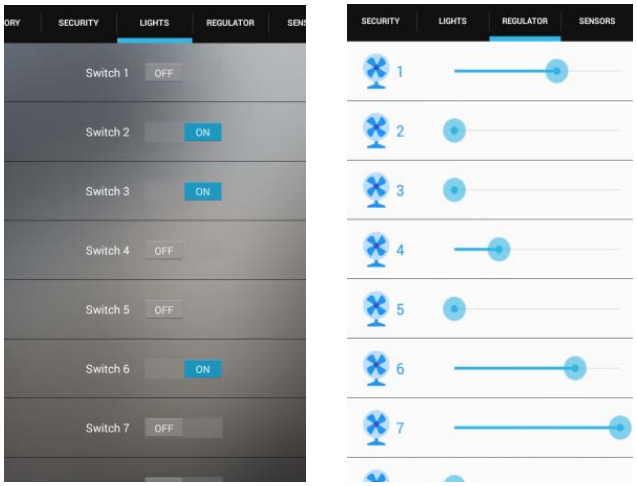


Fig. 6. Device Control screen.

Lights are switched ON/OFF and fan speed is regulated between 0-100% of maximum speed at user's discretion using Lights and Regulator interface screens of Android application respectively. For instance, lights 2,3 and 6 are operational depending upon the user requirement correspondingly by maintaining the switches 2,3 and 6 ON. From fig.5, it is noticed that fans numbered 2,3 and 5 are operated under zilch speed while fan 7 is operating at maximum speed and the rest of the fans are functional in the intermediate speed ranges. Like so, nimble monitoring and controlling of myriad lights and fans is possible at user's will.

To preserve the security of the establishment and ensure the protection of its inhabitants, Security management feature is employed. It detects the interference of unauthorized personnel and alarms the users. This feature also possesses a handy mode of switching OFF all the devices at one touch as shown in Fig.7.

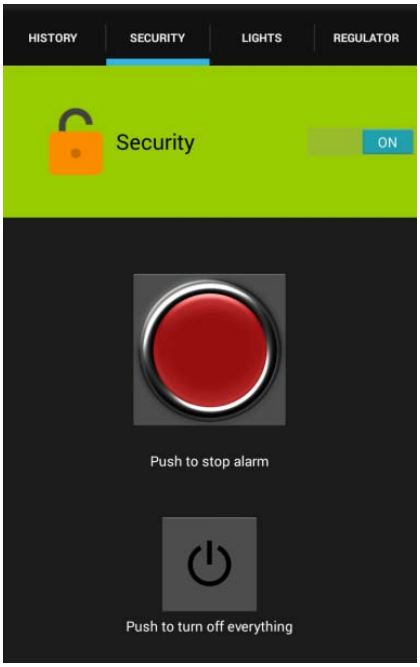


Fig. 7. Application window showing the master control switch.

The characteristics of user-oriented Smartphone app underscores the importance of HAS and is effectual in monitoring,controlling and security processes.

V. Conclusion and Scope for Future Work

In this work, the primary focus is on developing a technology which provides a cost-effective solution to Home Automation. The flexibility in the control of the designed smart phone based HAS is spread across the world as it can be controlled through the Internet. A wide range of sensors are used to capture the readings of temperature, humidity, water level, gas leakage and the flame sensing devices making it an efficient system for security as well as for monitoring. The specifications of this system and the ease of implementation aids large scale manufacturing and its acceptance in the industrial domain. In addition to the simplicity of the design, the application software embedded is Android, the most profound smartphone base and an open source which tags the smartphone to be the controller in this project owing to cost reduction aspect. With a relatively small overall cost of less than USD 100, this technology can prove helpful in the

societal causes of old age homes and orphanages. The future scope of this work is to develop an iOS application and a web portal. Knowing the power factor of the load, the energy consumption (kWh) and hence the tariff information of the beneficiary can be provided.

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