1st International Conference on Advances in Science, Engineering and Robotics Technology 2019 (ICASERT 2019)

Wireless Home Automation System Using IoT and PaaS

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***Abstract*—Home automation based on Internet of Things (IoT) is getting huge attention of mass people in recent years. Smart home eases and secures the management of the home appliances. This paper presents a low cost and reliable smart home system that assists the users to manage home appliances without the need of their physical presence. The proposed system includes smart door lock system using Radio Frequency Identification (RFID) card and password. It can store and display information of temperature & humidity of a home, and notifies the users of switching on/off time of light, fan and other home appliances using embedded micro-web server and an IoT platform. The user can also control the light intensity and fan speed based on LDR and temperature sensor values respectively. The system includes gas leakage & fire alarm. It has leakage gas removing & fire extinguishing facility and SMS notification system using IoT platform. The system uses real IP and RESTful API for controlling, monitoring and accessing the home appliances remotely from anywhere in the world using Android based smartphone app or web app. This system is user friendly and energy efficient.**

Keywords—IoT, PaaS, Home automation, Micro-web server, Teleduino, Altair SmartCore, RESTful API, Arduino.

I. INTRODUCTION

Internet of Things (IoT) is one of the mostly talked research topics in the recent years. IoT based home automation system is getting popularities day by day. Home automation is the controlling of the different home appliances using smart devices anywhere in the world without the need of physical presence in the home. Smart home system is very beneficial in everyday life as it saves electricity and reduces worries for home security of working people. Due to the secure, easily controllable and monitorable features, advanced home automation system design has become a core interest for many researchers.

Nowadays communication has become much easier due to the increased use of smartphone and laptop. People uses internet more than phone calls and SMS to communicate with each other. It is easy to process huge data faster and easier with the help of internet. Every day millions of devices are connected with internet in homes, schools, workplaces, and vehicles for helping people to live and communicate in a smarter way which is needed to analyze and translate via a gateway device. IoT platform can handle this kind of work. IoT platform is an important component of IoT that provides valuable application specific services in many application domains. Many kinds of IoT platforms are available nowadays [1] [2]. Platform as a Service (PaaS) is one of them, where the web developer has to take care only about the functionality of his application. During a development, he can use the API provided by the company to access important features of the PaaS, such as performing database operations, or managing users of his application [2]. An IoT platform is an integrated service that offers the user the things he needs to bring in online. It is capable of supporting millions of simultaneous device connections and easily allows the user to configure devices for machine-to-machine communication. In this paper, Altair SmartCore IoT platform [3] has been used which is based on the PaaS base IoT platform. This IoT platform has been designed in such a way where anyone can connect any type of electrical/electronic device. It can execute user command using it's REST API, manages devices where anyone can check the status of a load and can control remotely. This secured IoT platform can also send E-mail, SMS, and alarm. It can typically handle different tasks such as store data, visualize data and works as a middleware solution between hardware and application layers. The Altair SmartCore IoT platform does not apply any charge for connecting first two devices.

With the rapid growth of smart technologies and uses of electrical equipments (light, fan, etc.) and sensors (humidity, temperature, etc.), it has become very hard to control and get information from them manually. To getting control of that devices and measures the data from them, Arduino is an easy and cost-effective choice. Arduino Ethernet Shield is an Arduino extension which is used to connect Arduino to the internet for sending and receiving data and works as a micro-web server. When a user sends data as a command through the internet, this micro-web server fetches the data from the internet and sends command to the Arduino.

This paper is based on the design and implementation of a flexible, secured, low-cost, advanced home control and monitoring system. Home security includes services like gas leakage, fire extinguishing and trespasser protection. If any unauthorized person tries to enter the home, the system sends an SMS to the authorized phone number. The system has sensors. When the gas sensor finds anomaly, the system starts alarm through buzzer and the kitchen exhaust fan turns on automatically. Again, when the fire sensor finds anomaly the system starts alarm through buzzer and an emergency pump turns on automatically. The system sends SMS to the user for both cases. The system consists of a Teleduino server [4], micro-web server and Altair SmartCore server [5] for controlling and monitoring home appliances from anywhere and anytime. Each time with the change of state of any appliance, the information is stored instantly and the system notifies the user by E-mail. This stored data can be checked

978-1-7281-3445-1/19/$31.00 ©2019 IEEE

from anywhere by logging in Altair SmartCore web server. So, the proposed system allows authorized home owners to monitor and control the home appliances remotely using the 'Home Automation' android or web app through server real IP.

II. Related Work

Nowadays IoT makes technology more advanced. IoT is the network protocol integrated with physical devices, home appliances and other embedded devices which enables these things to connect and exchange data over a network without the presence of human being [6]. IoT has a novel impact on home automation system. Smart home is not a new term, it has been developed from over a decade. Home automation or smart home provides convenience, comfort, security and energy efficiency to its householders [7] [8]. Smart home consists of wireless technology such as Wi-Fi, RFID, Bluetooth and cellular networks. These have been utilized to various embedded systems which sense, control and exchange remote data.

The paper in [9] presents a smart home system where Bluetooth has been used as a medium of communication, without any internet connectivity. The physical devices such as sensors, actuators which can be accessed and controlled by smartphone using built in Bluetooth connectivity is implemented in [10][11].

To overcome the limitation of using Bluetooth signal (maximum range 100 m), researchers also introduced a popular technology called Wi-Fi based home control system [12] [13]. In Wi-Fi based home control system, a dedicated webserver and personal computer have been used, which is complex and not flexible.

GSM based cellular network has been applied in home appliances management system for longer range communication than Wi-Fi [14]. AT command is used to control and communicate with home appliances. The main drawback is that GSM has no suitable Graphical User Interface (GUI).

The authors in [15] have used MIT App Inventor, NearBus, and Arduino to develop a smart home prototype for controlling the home appliances without any monitoring capability.

Moreover, in papers [21][22][23], authors have designed Raspberry Pi based home automation system which is very costly. They have not used any IoT platform so their system is not capable of checking current status of home appliances. No security system is proposed there as well.

In paper [24], the authors proposed IoT based smart security and home automation system. They used PIR motion sensor-based security system and phone's digit pressing user interface for controlling home appliances using TI-CC3200 Launchpad board. Considering all these issues, an IoT based home automation system has been designed and implemented that can be controlled remotely from anywhere.

III. Description of The System

A. System Architecture

This section describes the details architecture of the proposed system. The system architecture is divided into five layers; remote login, server connectivity, real time database with notification system, home gateway and home environment.

Remote login allows the authorized user to login and access the system with 'Home Automation' app from anywhere in the world using Wi-Fi or 3G/4G network.

Server connectivity is controlled by Teleduino server, which links up between IoT platform and embedded micro-web server using a unique key. Teleduino converts Ethernet enabled Arduino into a versatile tool for interacting with devices over the internet. Ethernet enabled Arduino automatically connects itself to the Teleduino server when it is powered on.

Altair SmartCore web server stores data and works as real time database management system. When any appliances present state is changed, the server stores it and notifies the user by sending E-mail using Altair SmartCore Email API [3]. It also sends SMS for specific appliances (door, gas & fire sensor) it will send SMS using Altair SmartCore SMS API [3]. To get this facility, the user has to first create an account to the IoT platform.

Home gateway is an embedded micro-web server based on Arduino Ethernet Shield. The embedded micro-web server maintains and controls the home appliances using HTTP request by navigating Ethernet Shield's IP address through browser.

Home environment is directly related with home appliances. It consists of electrical equipments, modules and actuators. Module such as RFID [16] has been used for smart door lock system that ensures the entrance of authorized user only. This proposed system includes sensors such as temperature, and humidity for monitoring the home environment.

B. System Implementation

This section presents the explanation of working principle of the proposed system. The home gateway system is divided into two-parts; server connectivity and TCP/IP protocol. The server connectivity has three sections; Teleduino server, micro-web server, and Altair SmartCore server.

To implement the system, at first it is needed to establish a connection with Teleduino server, which creates a link between micro-web server and Altair SmartCore server. The user first sends initial standard HTTP command (using 'Home Automation' app) to embedded micro-web server through the Teleduino server. The micro-web server passes the command to the Arduino and the Altair SmartCore server.

The home gateway is connected to internet over TCP/IP. Arduino Ethernet Shield also supports TCP/IP stack. During the configuration with TCP/IP, the Ethernet Shield establishes connection with Local Area Network (LAN) using public IP address. Thus it creates an embedded system using TCP/IP protocol [17]. Once the home gateway is initialized, Arduino gets ready to execute any command. Then it enters into idle state until any further command is received from the remote

user. When the user sends HTTP command successfully from the 'Home Automation' app, Arduino Ethernet Shield decodes the command and Arduino takes appropriate action accordingly. At the same time the decoded command is stored in the Alter SmartCore server and notifies the user through E-mail. The complete process is illustrated as a flowchart in Fig. 1.

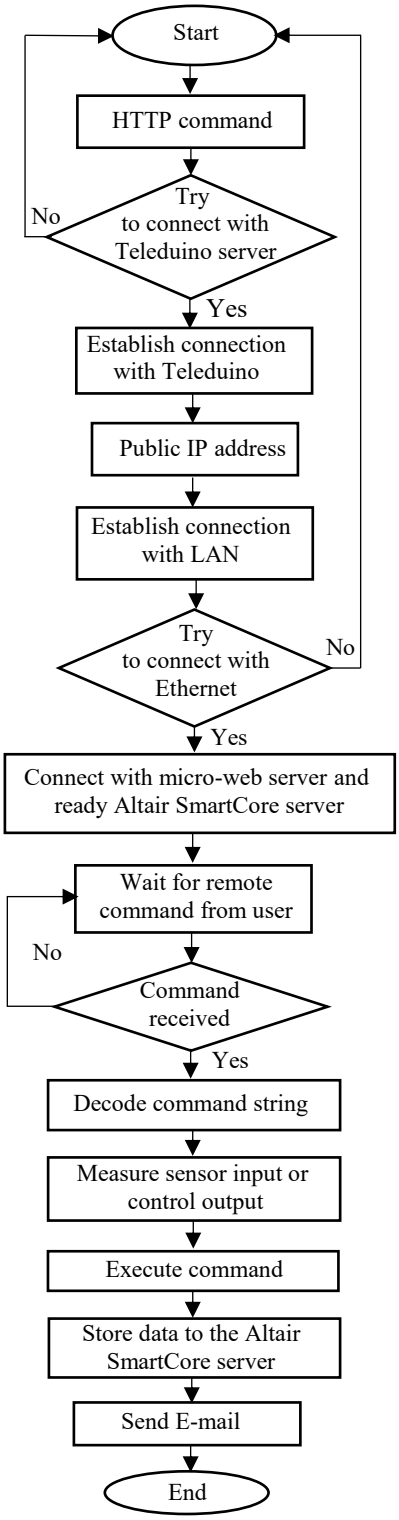

Fig. 1. Flow chart of E-mail notification process.

The home automation system includes some sensors and modules. The gas sensor detects gas leakage, fire sensor detects fire and keypad module is used for pressing password. The Arduino microcontroller is used to collect and analyze sensors data and controls the decision-making process. The Altair SmartCore server stores the data and sends SMS. The complete process is shown in the following flowchart in Fig. 2.

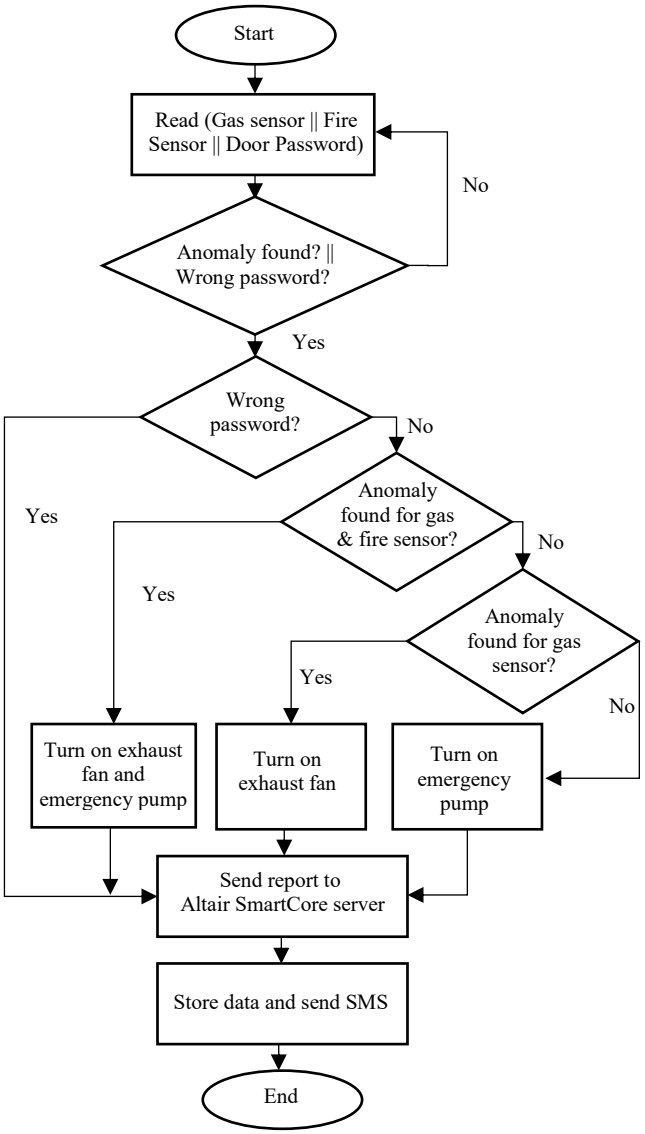

Fig. 2. Flow chart of SMS notification process.

C. *SystemFramework*

The home gateway framework is closely related with web services. The access and manipulation of web services have to be easy, direct, simple and interoperable. This eases the communication between the client and server applications of remote services. Web services are XML-based or JSON-based information exchange systems that use the internet for direct application-to-application interaction [18]. These systems can include programs, objects, messages, or documents. There are two main classes of web services; Simple Object Access Protocol (SOAP) and Representational State Transfer (REST). RESTful web service has a great deal with flexibility. It is much more stateless and lightweight than SOAP that offers functionality similar to SOAP based web services [19].

Therefore, this proposed system has used RESTful based web services. This service utilizes two standard operations: POST and GET. These two operations request and return

JSON response to communicate between the remote user and the micro-web server. JSON is much more lightweight for storing and exchanging data over client-server. It is easy for human beings to parse and generate messages simpler and faster than XML. For example, to turn a light on, an HTTP POST sends a request to micro-web server via Teleduino Server. After a successful operation the system sends response with success status response code "status": 200. The complete operation is illustrated as a data flow diagram in Fig. 3.

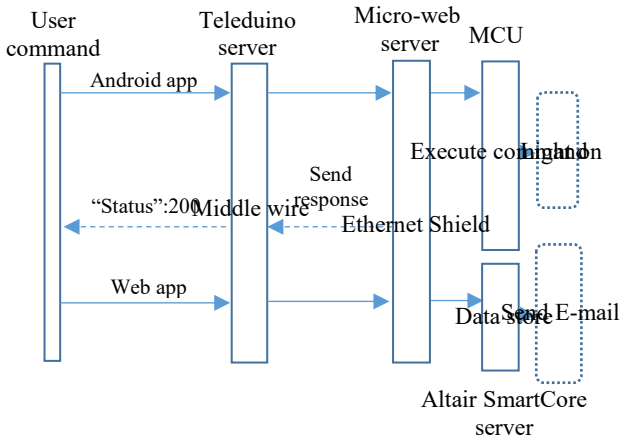

Fig. 3. Data flow diagram of web services.

D. *Smartphone and Web Application*

There are several platforms for developing smartphone application such as Android, Windows Mobile, iOS and others. About eighty eight percent people of the world use Android operating system as Android GUI is much simple and sophisticated [20]. Web application has been used productively because of the increased availability of information. These increases have led to heavier reliance on web-based application. Also, a web application can access anytime, anywhere through any web browser in any operating system with an internet connection. That is why this proposed system introduces both web application and smartphone application to control the home appliances. Fig. 4 and Fig. 5 illustrate the GUI of 'Home Automation' Android app and web application.

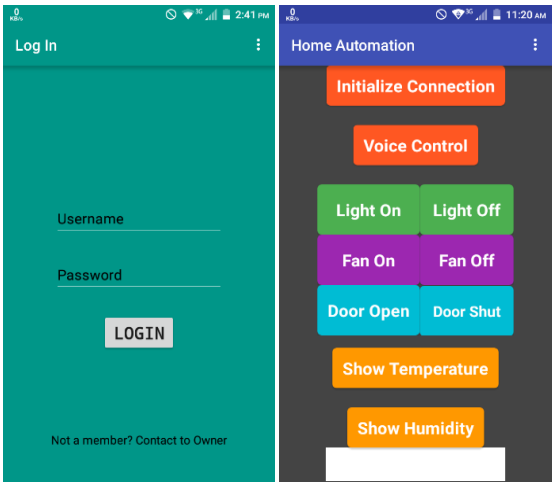

Fig. 4. Snapshot of 'Home automation' Android app with voice control option.

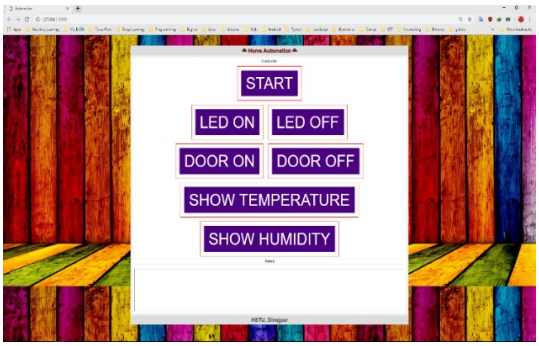

Fig. 5. Snapshot of 'Home automation' Web app.

To successfully control home appliances with home gateway, a user has to first connect with Teleduino server. When a user sends any command via 'Home Automation' app the micro-web server fetches it and forwards the request to the Teleduino server. The Teleduino server responses according to the command and sends back as JSON format to the user.

IV. Experimental Setup And Hardwire Configuration

The home automation system has used Arduino Mega as microcontroller board which works as the central control unit. Various modules including gas sensor, temperature and humidity sensor, RFID module, keypad, LCD, Relays and light/fan are interfaced to the Arduino board for testing the project. The experimental configuration and implementation of speech or manual control based home automation system are shown in Fig. 6 and Fig. 7.

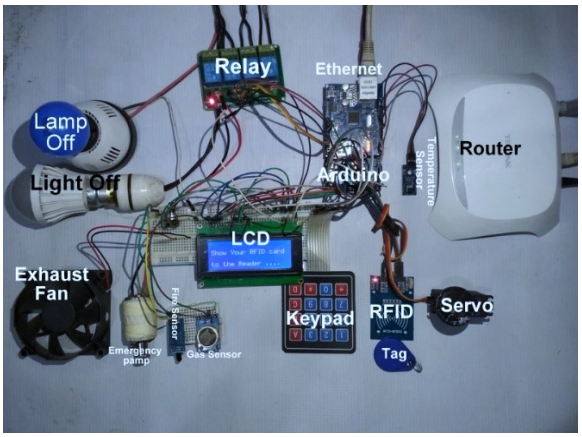

Fig. 6. Experimental configuration and implementation of home automation system with light and lamp off.

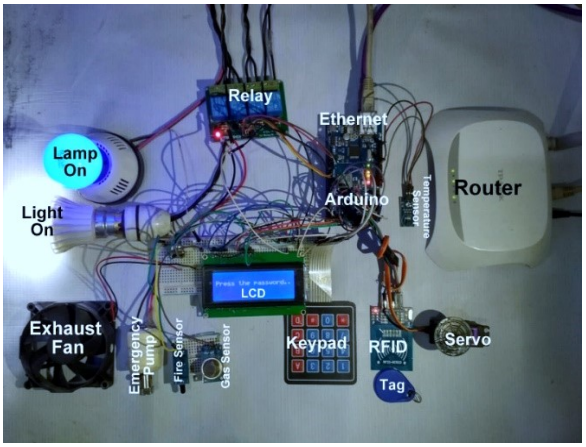

Fig. 7. Experimental configuration and implemented result of home automation system with light and lamp on.

This microcontroller board is interfaced with Arduino Ethernet Shield based on Wiznet W5100 Ethernet chip. The Arduino mega and Ethernet Shield are used to implement the micro-web server for home gateway control system. The Arduino mega 2560 is a microcontroller board based on the ATmega2560. A conventional light switch is integrated with Arduino using relays to demonstrate the switching capability. This system has sensors which detect input signals and actuators that perform responsive and adaptive functions. The experimental Setup of home automation system is shown as a block-diagram in Fig. 8.

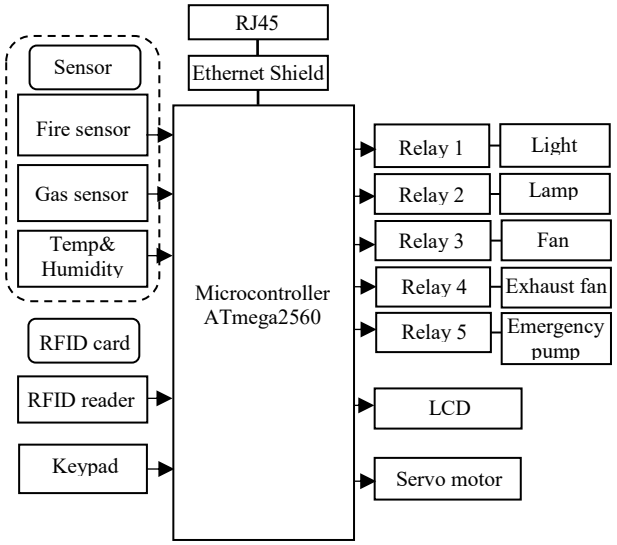

Fig. 8. Block-diagram of complete home automation System.

To configure this system, the user must connect with server through home gateway. To authenticate the user and to control the home appliances user has to first login and send initialize command through apps (smartphone/web) which will activate Ethernet Shield.

V. Comparison Study

A comparison study has been performed to measure the performance of the proposed system with other recent works. A table has been given below to compare the features of the existing works with the proposed system. The performance metrics cover many aspects such as real time database, instant notification through E-mail and SMS, control and monitor home appliances from anywhere and user interface. The TABLE I. shows that the proposed system is better than all others.

TABLE I. Comparison with Existing Works

Paper Ref. No	Performance Metrics				
	Real Time Data base	***Instance Notification***	***Control home appliances from anywhere***	***Monitor home appliances from anywhere***	***User interface***
[21]	No	No	No	Yes	Web app
[22]	No	No	No	Yes	Web app
[23]	No	No	No	Yes	Web app
[24]	No	Yes	Yes	No	Digit of a phone
Proposed system	Yes	Yes	Yes	Yes	Android and Web app

VI. Conclusion

In this paper, an android and web based multi-functional advanced home automation system has been designed and implemented. The proposed system ensures easy and proper control of the home appliances from anywhere in the world. This system provides more security to a home by preventing intruders. It also protects a home from accident by removing leakage gas and fire extinguishing facility. This system is very beneficial for old ages, handicapped people and working people. The complete system has been tested and performed as expected. The GUI is user friendly and more practicable. The system ensures flexibility, reliability, energy efficiency, and a smart home.

VII. Scope for Future Work

In future, the home automation system would be made more functional. More home appliances will be included in the system. To improve the security of the system, facial recognition technique will be applied.

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