

A Building Automation System Demonstration

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Abstract

This paper presents a building automation system based on the Arduino hardware and Android software. The system supports various sensor functions with a very practical and low cost system configuration. Android blocks that control the Arduino components and sensors are developed with MIT App Inventor 2 software. Additionally, all Arduino components and sensors are put into an unique demonstration model with the purpose of test of the system and the presentation in real-time. With this model, smart building environment is animated and correspondent functions become more understandable. Presented system that supports comprehensive functions has also potential for educational usage and teaching activities due to its practical configuration.

1. Introduction

In recent years, *smart home* concept has emerged and gained popularity with the technological developments. Building automation systems offer many applications in the house that ensure the comfort and efficiency. The importance of the Internet of things has an incontrovertible effect on the development of this concept. In daily lives, intelligent household appliances and furnishings save the time and effort, increase the life standards and provide the security in different ways. Additionally, building automation systems have high levels of simplicity and availability through smart devices.

Building automation systems are the smart systems that involve combination of suitable software and hardware which are used for automation of electrical systems [1]. These systems ease usage of important functions such as heating, cooling, lighting, fire extinction and security. Some building automation systems can also provide emergency evacuation service. However, current applications have a common problem, such comprehensive functions operate in isolation, can not be managed in overall fashion although overall management's huge potential in future applications. European Union funded Building as a Service (BaaS) project deals with this problem which aims to provide a comprehensive software platform for current and future commercial building management and building technology, with flexible and cost efficient integration of mentioned services, a overall management concept is targeted [2].

As rising concept, building automation integrates many applications which can support different usages. For example; a servo motor can be used to control the door; on the other hand

it is suitable for pet feeding. Similarly, all domestic activities can be adapted to automation concept by the help of facilitating the electronic components [3]. The remote access renders it more practical and useful in the home environment. When all of hardware based services and user friendly interface are combined in a system, the rise of building automation system is inevitable [4]. For such combination, security is a significant issue. As an exemplary solution of this problem, in our system, motion sensors and door controls are utilized in order to get information about unusual activities like a burglar at home. Moreover; gas, smoke and fire sensors give constant information about extraordinary situations and raise alarm. Hence; a home accident and maybe massive disaster can be prevented. Due to all of these reasons, building automation systems are favorable and feasible in terms of answering to user requirements.

According to the market research results, about building automation market, revenues from this concept is estimated to over 12 billion \$ by 2020. The growth in this area is expected to increase of 11.36% from 2014 to 2020 [5]. The growing and advanced developments in wireless technologies bring excessive increase in innovations about building automation systems. In line with the efforts in BaaS, we are also aiming the overall management concept in building automation systems. In this paper we manage some of mentioned services in overall fashion and present results with a demonstration model in real-time.

In this work, building automation system is developed by composing Arduino circuit that includes smart home functionalities via connected sensors which are controlled by an Android based application via serial Bluetooth connection. The fundamental controls like lights, door, temperature, moisture, fire and gas alarms are all included in this project. Moreover, system's functionality is shown in real-time by an unique developed demonstration model which indicates system properties clearly and possible benefits of building automation system in a modeled home environment.

2. Related Works

In literature, there are various building automation implementations that mainly involve Arduino and Android based configurations. In [8], a home control and monitoring system that is implemented using an embedded Arduino Ethernet based micro-server with IP connectivity for realizing controlling functions with Android based Smartphone app. System's functions include light switches, power plug, temperature sensor and current sensor. Authors of [9] have developed a system using Android to ease disabled people's daily life activities. Application offers wireless control, switch on or off func-

tions for electrical devices. System is implemented with PIC microcontroller, PIC16F877A. Application is managed with serial Bluetooth connection between microcontroller and application. In [10], a low cost, flexible and secure automation system is demonstrated. System is implemented Arduino BT(ATMega 238) board and an Android application is generated. Connection between board and application is provided by wireless serial communication over Bluetooth. Moreover, a Linux based web server is used for usage from outside the house. System is able to control TVs, fan and tube lights via Android phone. Target device can be turned on or off and correspondent status is shown. Furthermore, with timer functionality, device can be switched on for specific time. In study [3], a low cost and flexible smart home system has been developed. Home system functionalities are controlled via an Android app with Arduino Ethernet based micro-server communication. Functions like light switches, power plugs, temperature sensors, humidity sensors, current sensors, intrusion detection sensors, smoke/gas sensors and sirens are offered and managed by Arduino microcontroller. A building automation system is shown in [11]. Arduino microcontroller is used as main controller and Android is used for application. System provides both wireless Zigbee and wired X10 technologies. System also offers a scheduling algorithm for more functionality. Switches that are sending environmental information and actuators that perform specific tasks are managed by this system. In [12], a low cost and wireless remote control supported building automation system is shown which is designed for disabled and elderly people. System provides the physical switches with modified low voltage activating method. PIC Microcontroller, PIC18F2550 is used as main controller and an Android app is developed as user interface. Communication between hardware and app is provided via Bluetooth connection. Sensors that are used for measurement of room temperature and humidity level, are managed with this system. A building automation system that supports two user friendly interfaces such as an Android application and a web application is shown in [13]. The system includes three components as local hardware, web server and mobile smart device. Google Cloud Messaging is used for connection of system with the local hardware and the mobile smart devices. An Android application is also developed as user interface tool. Prototype implementation supports control of smoke sensor, automatic switch and an air-conditioner. In [14], for cost efficiency and preventing electrical hazards at home, a real time power monitoring system based on an Android application and wireless sensor network that is monitoring electricity usage characteristics continuously. According to algorithm, to measure electrical usage, sensors measure voltage, current and temperature, if measurements are higher than threshold levels, sensors share this information to a master node. A graphical user interface is provided to the monitor and log sensor events. An Arduino based home and building automation system that targets practical electronics teaching is demonstrated in [15]. The system is developed as an outcome of a comprehensive project. System's functionalities are access control, climate control, lighting control, energy management, technical alarms and integration with mobile technologies. In project, four subprojects are implemented such as energy efficiency, comfort, security and communication subprojects that include lighting and energy management, control of air conditioning systems, design of alarm management system, RFID access control system and assistance and surveillance control system, finally embedded web, iOS and Android app design.

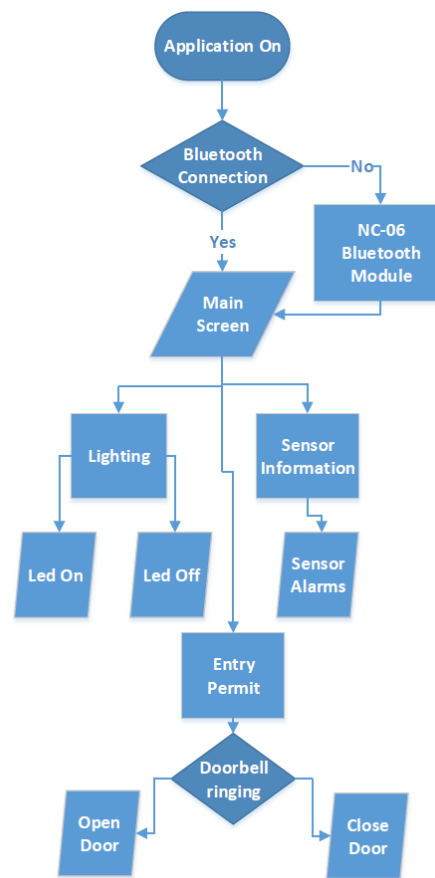


Figure 1. Block diagram of the designed and developed application.

3. Implementation

In this section, details of the proposed Arduino and Android based building automation system via Bluetooth connection application's implementation are explained. Project's progress and followed steps are showed in Figure 1. As it can be seen from figure, project consists of three subprojects called as Android, Arduino and Model respectively. In Android part, we constitute Bluetooth connection firstly, then smart home functions such as lighting, entry permission and sensor implementations are implemented. In result an Android app is created. In Arduino part, part is determined by analysis of literature usage and available products in market. After selection of Arduino, HC-06 module's connection is provided, circuit and components are connected and by completion of Arduino programming, Hardware Implementation is done. In Model part, smart home demonstration model is designed and created. In result, all of the subprojects are combined as targeted project. Application's content and options for users are explained in block diagram in Figure 2. After application is opened, firstly Bluetooth connection is asked, if answer is *no*, then HC-06 module takes responsibility and if connection is provided main screen is opened as in the case of result of answer is *yes*. Then three options are provided to user. If *Lighting* is chosen, user can open LEDs by choosing *Led on* or can close by choosing *Led off*. If *Sensor Information* is chosen, then sensor information are

shown in screen and information can be monitored by user. As last option, if *Entry Permit* is chosen, user can monitor whether doorbell is ringing or not and can decide to opening door by choosing *Open Door* or closing door by choosing *Close Door*.

3.1. MIT App Inventor 2

MIT App Inventor 2 is a block-based programming tool that provides functional Android programming [6]. It differs from other text-based Android tools due to low complexity of the programming method. A programmer can prepare code easily with MIT App Inventor 2 tool without dealing with any text-related programming errors, moreover; user can focus on algorithm more efficiently than other text-based programming tools users.

MIT App Inventor 2's programming method is executed by creating algorithm by connecting blocks which include embedded Android libraries' codes. Without any downloading requirement. It's through its website. MIT App Inventor 2's programming interface consists of designer and blocks sections. By selecting designer section, user can see how application interface will be. In designer user can change interface configurations like font setting or button shapes. In blocks section application's code is prepared by using blocks from different libraries on the left side of the interface.

An example of the MIT App Inventor 2's view is showed in Figure 3. In our project, we used MIT App Inventor 2 for programming of Android application. With this method, significant practicality is provided to the system.

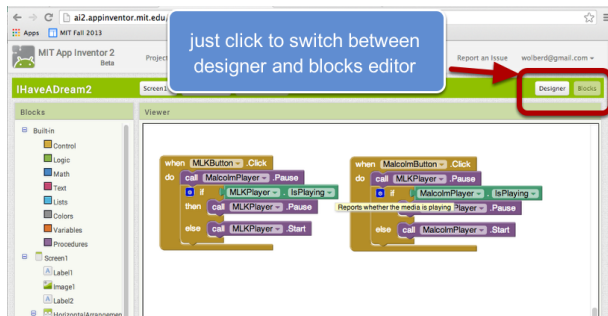


Figure 3. An example of the MIT App Inventor 2's view.

3.2. Arduino

Bluetooth connection between phone that runs application and Arduino that controls smart home functions are provided by HC-06 Bluetooth Module. HC-06 is used for wireless serial connections. It can be used with Arduino easily. It operates at 2.4 GHz and supports Bluetooth 2.0, moreover; its connection range is up to 10 meters [7]. In our configuration, HC-06 is controlled by Arduino as slave.

3.3. Application

Android based building automation system via Bluetooth application is prepared in MIT App Inventor 2 with Android software development kit. Application contains 5 screens. In first screen, Bluetooth connection is set up and if it is actualized without any problem, application allows user to pass to other screen. Second screen is the main screen of the application. It includes options to choose one of the three smart home functions which are LED lighting, sensor and door controlling.

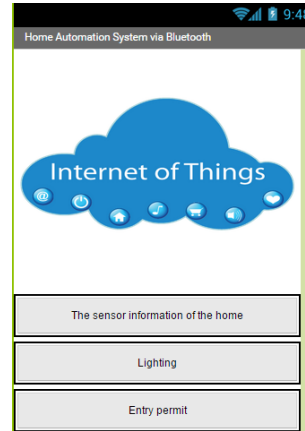


Figure 4. Application's Screen 2's view.

A user can have access to other screens according to his/her selection. Bluetooth connection is controlled in every screens to prevent errors. Screen 2's view can be seen by Figure 4. In third screen, LEDs that are connected to the Arduino are controlled by *Lighting on* and *Lighting off* buttons, which open LEDs or close LEDs respectively. Door is controlled by forth screen. It includes *Open Door* and *Close Door* options to open or close the door respectively. It also includes a text box to inform user if door is ringing by receiving ringing information by Arduino via Bluetooth connection. This is provided by constant refresh of the Bluetooth connection between phone and Arduino to check whether ringing information is coming or not. In fifth screen a sensor is controlled.

4. Results

We designed Android and Arduino based building automation system application by using Arduino Uno and MIT App Inventor 2. Firstly, we prepared our Android program in MIT App Inventor 2 which includes commands to control Arduino and connected pieces. Secondly, we prepared an Arduino code to control Bluetooth connection with phone that runs application and elements connected to Arduino. In the end, we brought all together in a demonstration model. Android application of the system's screen views can be seen from Fig. 6a and 6b whose details were explained in Implementation Section. Arduino circuit is prepared with necessary sensor, lighting and Bluetooth module connections. Circuit model can be seen from Fig. 7.

Building automation system's unique demonstration model is shown in Fig. 5. Model was built with foamboard and a sample home environment is modeled. Lighting system of sample home is modeled with LEDs. Door controlling is modeled with a sample door that is controlled by servo. Also some sensors are placed in model. With building automation system application, we can control LEDs by "Lighting" screen, servo controlled door by "Entry permit" screen and sensor information by "The sensor information of the home" screen. As explained in Implementation Section, building automation functions are realized successfully in all automation options.

As shown in Table 1, system's maximum load to network has length of 2871 bits. These configurations are not changeable due to Bluetooth module's settings; however, baud rate can be changed, in our system its default value is 9600 bps. Although maximum network load is quite high, our system does not work

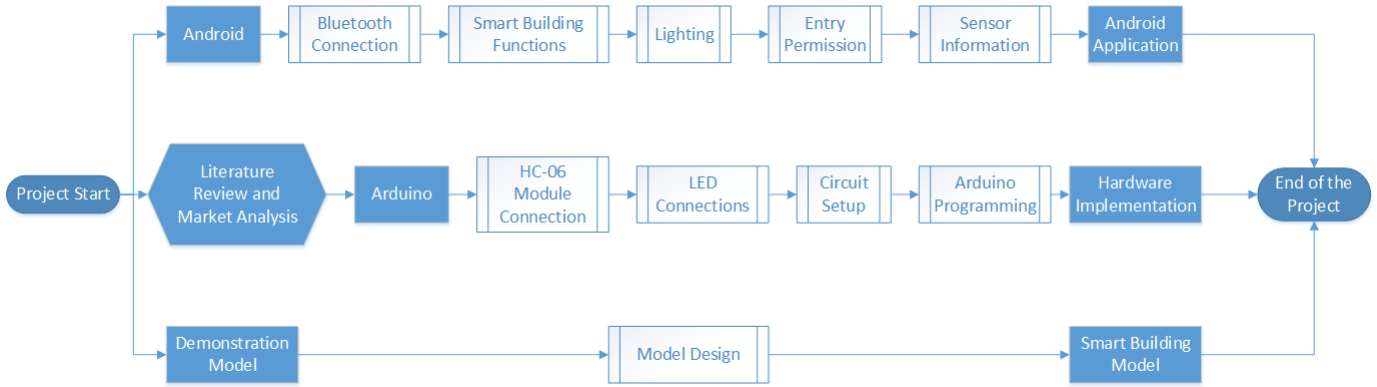


Figure 2. Block diagram summarizing the process flow.

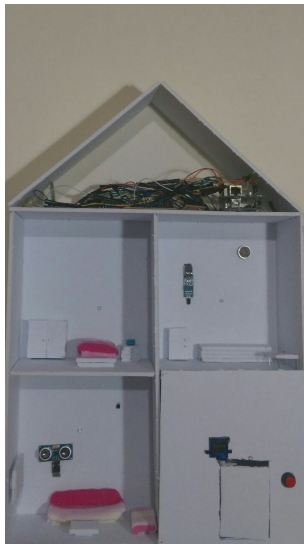
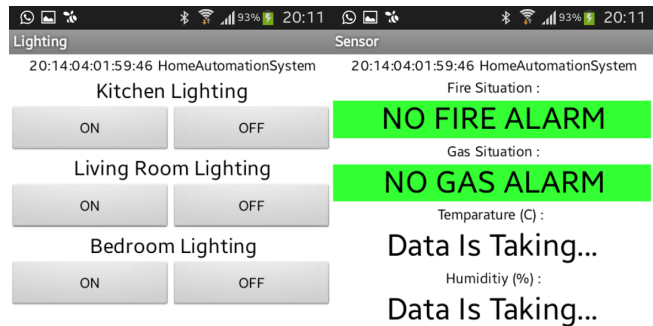


Figure 5. Building automation demonstration model.

with this capacity. For example, when a command of Android application of the building automation system is run, it is only sent with 5 bits. Thus it can be said that building automation application is quite efficient in the by means of network usage.

5. Conclusion

Building automation is a novel concept that offers a lot of services to improve people's daily comfort in home environment. Building automation systems' importance for commercial buildings is increasing day by day due to their very beneficial services like climate control, visual comfort, personal safety and building security. In line with the objectives of the BaaS project, in this paper, an Android and Arduino based building automation system via Bluetooth connection is proposed. System includes Android application that contains building automation commands and Arduino circuit which can implement some building automation functions with connected LEDs, sensors and Bluetooth module. Android application and Arduino components' communication is provided wirelessly with bluetooth module. As in BaaS project, overall management of these services are provided. Furthermore, an unique demonstration model is developed and building automation sys-



(a)

(b)

Figure 6. Lighting and sensor information screens' views respectively.

Table 1. System's maximum network load values .

Baud rate	9600 bps
Maximum packet bit capacity	2871 bits
Access code	72 bits
Header	54 bits
Payload header	8 bits
Payload	2712 bits
CRC portion	16 bits

tem is shown in real-time. This model improves system's visibility and shows the details of the functions. With very low network usage, system is implemented successfully. In future, this work can be extended with more building automation functions and can be used in more general scenarios.

6. References

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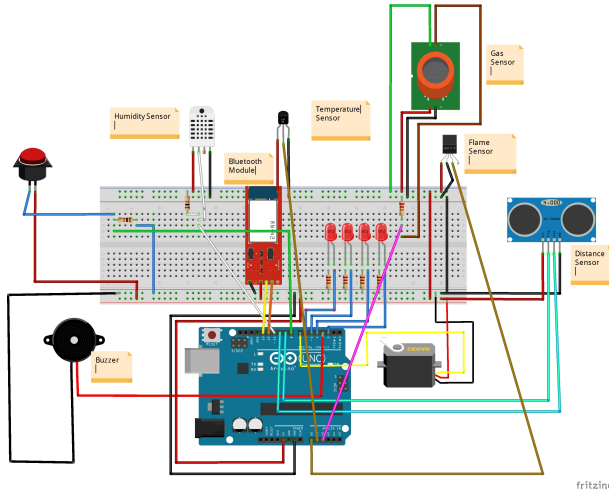


Figure 7. Arduino circuit's screen view.

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