IoT-Based Interactive Dual Mode Smart Home Automation

Omar Hamdan, Hassan Shanableh, Inas Zaki. A. R. Al-Ali Senior Member, IEEE,
and Tamer Shanableh, Senior Member, IEEE
American University of Sharjah, Sharjah, UAE
(b00057329, b00057346, g00057594, aali, tshanableh)@aus.edu

***Abstract*-- Smart home appliances nowadays can be networked utilizing the IoT communication protocols. Appliances can be monitored and controlled using local switches and remote access via mobile phones. Many systems are reported in the literature based on single monitoring and controlling mode utilizing text, voice or gesture commands. This paper presents an IoT-based Dual-mode system to monitor and control home appliances. In the proposed system, home appliances are interfaced with a general-purpose digital and analog inputs and outputs of a single chip microcontroller. The microcontroller has a built-in wireless access point that enables the system to communicate with a home server. The system has two different operation modes. The first mode makes use of a mobile app interface with virtual switches and sliders to monitor and control appliances. The second mode is chat-based that uses text or audio commands fitted with natural language processing to monitor and control the home appliances. The proposed system is scalable in that it is able to add and remove rooms on demand. For validation and testing purpose, a prototype is built that includes home appliances, room controllers, home server and a mobile app.**

I. Introduction

Smart home remote monitoring and controlling systems are not new. In the literature, many systems are reported and implemented using single chip controllers to monitor and controller home appliances. Communications protocols such as Zigbee, Bluetooth, WiFi, GPRS, Ethernet, Power Line Carrier (PLC), SPI, I2C and RS485 communication protocols are used to interface the home controllers to the Internet.

For example, a recent IoT-Cloud based smart home automation system using a web platform to control home appliances was reported [1]. In this system, a homeowner can change the appliances' status using HTTP requests. The important feature of the IoT-Cloud approach is to store the home appliances' status and perform more data analytics. An end-to-end text-based remote control system for home appliances using a secure mobile applicant was reported in [2]. Based on ZigBee and PLC, an energy management system was reported in [3]. The system monitors and controls lights, the status of appliances, and energy consumption via the Internet based on text commands [4].

The above-mentioned systems use mobile and internet applications, however they are limited to text-based commands.

This paper proposes an IoT-Based Dual-Mode Smart Home Automation System that uses a touchscreen interface mode and Natural Language Processing (NLP) mode. A mobile app is developed to enable home users to monitor and control their home appliances using mobile. The proposed system has an additional advantage of scalability where new rooms controllers can be added/removed on demand.

II. Proposed System Requirements

Requirements are an essential part of designing a reliable, maintainable, robust, scalable, and secure system. The proposed system should have the following functional requirements:

- A homeowner can use a mobile device to access all home appliances using touchscreen commands.
- A homeowner can use a mobile device to access all home appliances using text or voice commands through NLP.

The proposed system nonfunctional requirements are:

- Ease of use and friendliness.
- The system should not take more than 100 milliseconds to respond even when querying database.
- User interface should be rendered and response received on a separate execution thread in a reasonable time.
- The system must be secure.

To satisfy the above requirements, the proposed system has the following hardware and software architectures.

III. Proposed Hardware Architecture

The proposed system hardware architecture consists of room controllers, a home server (home gateway), a cloud database server and home owners' mobile units. Figure 1 shows the proposed system high level hardware architecture. All room controllers and home servers are implemented using the ARM single board microcomputer [5]. Each ARM board has 1.2GHz speed CPU, a 1 GB RAM, a 32GB SD memory, a built-in wired communication interface such as 4 USB, 2 SCI, 2 SPI, I2C, a Bluetooth and WiFi wireless access point as well as an Ethernet port. Wired communication interfaces are used to connect switches, sensors and actuators to the controller units. The controller is a credit card size, and cost about $40. The WiFi is utilized to connect room controllers to the home server; and later to the Internet. Home appliances are interfaced to the room controllers' GPIOs through input signal conditioning circuits and output driving circuits. The home server is utilized using single board computer [5] and it has been utilized as the link between the room controllers and the cloud database server. Homeowners can access each home appliance using their mobile devices through a cloud-based database server.

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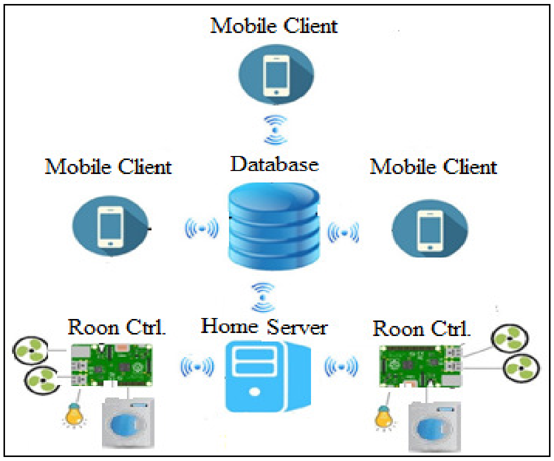

Fig. 1. High-level hardware architecture of proposed system

IV. PROPOSED SOFTWARE ARCHITECTURE

The software architecture is divided into three main modules; the Rooms' controllers, home server and the mobile application. Figure 2 shows the proposed system high level software architecture:

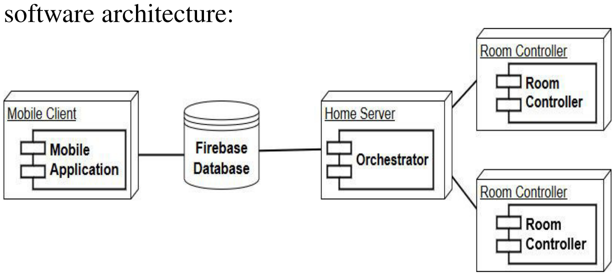

Fig. 2. High-level software architecture of proposed system

A. The Room Controller Module:

Each room controller is responsible for getting appliances' statuses and passing commands onto appliances in real-time. Upon receiving a request from the home server, the room controller will reply with the requested appliance status or actuates/changes appliance status.

The room controller most important functions are:

- applianceManager() function: This function translates a string sent by the server into a list of commands and actuates these commands on the physical appliances.
- TCPSocket() function: This function receives data from the server over a socket, and decrypts the data using a secure AES encryption implementation.

B. The Home Server:

We implemented the home server using Raspberry Pi 3. It provides scalability and ease of setup. Each room controller is added to the system will communicate with the home server, the server will automatically assigns a unique ID for the room. The main server module functions including:

- net.createServer(): this function creates a socket and listen for incoming connections from room controllers. Once a connection is heard, the server will process it and pass the incoming data to the relevant functions and modules.
- firebase.readFromDB(): This function assigns a listener for the connected room to listen for changes and binds this listener to a callback function that will send the data back once a change occurs. Also, it will send the current snapshot of the data back to a connected client upon its initial connection. Furthermore, it can read data from the database at a selected node or level.

Moreover, the server provides security implementations for the system, and creates a logical link between the components.

C. Mobile Application:

The mobile client App runs the mobile application module. The mobile application module provides an interface via a virtual buttons and sliding switches that enable the users to remotely monitor and control home appliances. Alternatively, the mobile application module allows users to monitor and control appliances through NLP using text chat or voice commands. Figure 3 shows some of the system screenshots.

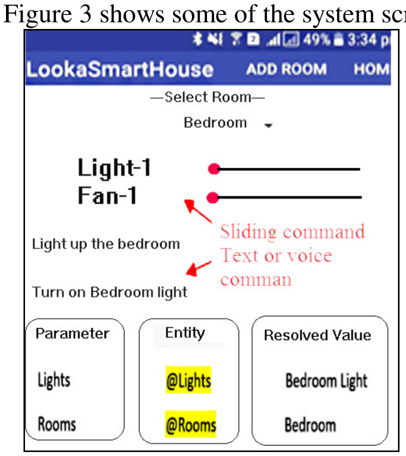

Fig. 3. Sliding switches, text and voice commands screenshot

V. CONCLUSION

An IoT-based interactive smart home automation system is designed and implemented. The system used compact, low power and low cost single board computing platforms. Using mobile phones, users can activate virtual buttons and virtual sliding switches as well as type text and voice commands to monitor and control home appliances from anywhere anytime.

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