Implementation of Smart Home Solution based on Internet of Things

Conference Paper · November 2019

DOI: 10.1109/TELFOR48224.2019.8971294

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Implementation of Smart Home Solution based on Internet of Things

Andrej Jovanov, Jane Lameski and Biljana Risteska Stojkoska

Abstract — **With the advances in information and communication technologies, small tiny devices capable to sense the environment became cheap and affordable. This opens many new possibilities to design cheap and simple solutions for monitoring indoor and outdoor environments. In this paper, we have designed and developed a complete system based on Internet of Things technologies for indoor temperature regulation. The main contributions of this paper are: (1) to remotely regulate the temperature in a condominium-based apartment; and (2) to provide apartment temperature zoning in order to save energy. Our system combines state-of-the-art off-the-shelf hardware components and embedded software to create a contemporary solution.**

Keywords —**Indoor Temperature Regulation, Internet of Things, Smart Home, Raspberry Pi 3.**

I. Introduction

INTERNET as a network, can expand the connectivity beyond standard devices such as laptops, desktops, smartphones and tablets, to any range of non-internet-enabled physical devices and everyday objects, allowing them to be remotely monitored and controlled. Internet-connected consumer devices ("Internet of Things," "IoT," or "smart home" devices) have rapidly increased in popularity and availability over the past several years. IoT is a network of devices, including vehicles and home appliances that consist of electronics, software, sensors and actuators, being able to interconnect, interact and exchange data of interest [1].

With the advances of information transmission systems [2], traditional power grids are continuously replaced by smart grids, allowing better control of power production, transmission, distribution and consumption [1]. Smart home, the last part of the smart grid, consists of households that actively participate in the electricity consumption. Smart homes can be found useful in many views, especially in terms of shifting loads from peak to off-peak [1][3]. Smart home, previously known as Home Automation System [8], is defined as a new concept using devices connected with each other to automate and monitor in-home systems. Originally developed by IBM, this technology stands for Self-Monitoring Analysis and Reporting Technology. Users can remotely control connected home systems whether they are at home or away, granting efficient energy and electricity usage, as well as ensuring home security.

Until recently, this kind of managing required big efforts and commitment from the users. There were a few home automation solutions, but they were affordable only to a small and limited wealthy population. With the advances in communication technologies and the development of Internet of Things [4], [5], [6] real-time monitoring systems [7] became cheaper and more affordable for the general population.

Still, the traditional home has appliances that are operated locally and manually, typically by flipping a switch or pushing a button, implying that energy management can be difficult [1]. The aim of this work is to implement cheap solution for smart home. We will be discussing our implementation using Raspberry Pi 3 (RP3) [9]. Our system will reduce the cost for heating and cooling, enable remote control features and provide multi-zone regulation of the temperature in a condominium-based apartment.

This paper is organized as follows. In the next section the problem will be described. The third section presents the system architecture including all hardware components used for the solution. Software implementation is elaborated in section four. This paper is concluded in the fifth section.

II. Problem description

Cevahir is a holding company in constant growth, which operates multiple industries including construction. In Macedonia's capital city Skopje, the first skyscrapers developed by Cevahir were brought to the market in 2011 (Fig. 1). Currently two of the four skyscrapers are finished, and the other two are still under construction. The inspiration for our research work is a problem which occurred in a one of the buildings' fourteenth floor fifty square meters apartment, with a manually controlled heating and cooling system (Fig. 2). Every room in the apartment is heated/cooled equally, according to the temperature being set on only one controller, placed close to the entrance of the apartment [10]. This controller has temperature sensor and its measurements are used to

This project was financially supported by the Faculty of Computer Science and Engineering.

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control the heating/cooling process in all rooms at once (Fig. 2). There are three heaters/coolers, one in each room. They can be automatically controlled be the central controller. Additionally, they can be controlled manually, which requires rotating the dampers based on users' intuition.

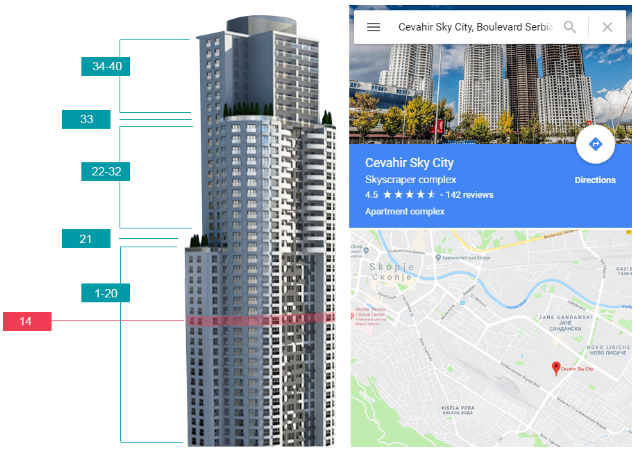

Fig. 1. Cevahir Sky City tower [11].

Because there is only one temperature sensor in the apartment, when the system is heating the rooms, the cold air from the rooms is flowing beneath the doors into the entrance hall, producing low temperature readings on the sensor. Therefore, the real temperatures in the rooms are actually much higher than the temperature being set on the controller. Thus, one has to manually turn on-off the system, besides the automatic temperature handling option given in the controller features. Additionally, if one wants to stay in the living room at given temperature for longer period of time, the rest of the rooms are heated/cooled without necessity, which contributes to increased energy consumption.

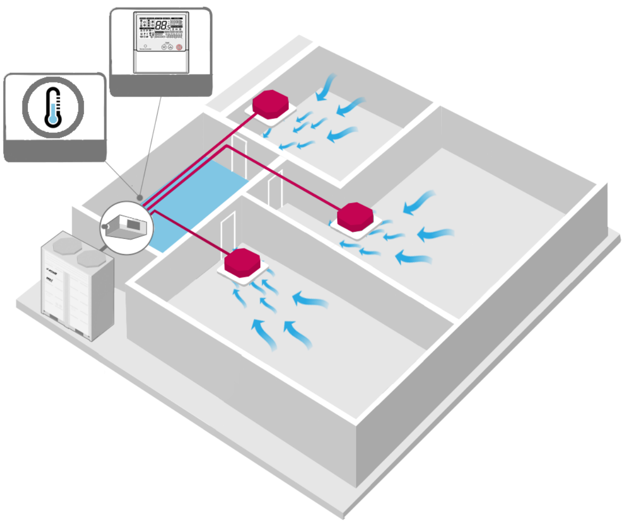

Fig. 2. Heating-cooling system problem, inaccurate temperature readings.

The aim of this paper is to extend the current solution of the heating/cooling system, by implementing zoning, remote monitoring and remote controlling. Thus, the system's desired temperature accuracy will be improved, and the electricity consumption will be decreased.

III. System Architecture

In this section, the system architecture will be described in detail. The UML deployment diagram is given in Fig. 3, showing the main parts of the system, namely the Raspberry Pi 3 (RP3), the temperature sensor, the motor that controls the dampers, and the personal computer/smartphone to remotely control the system.

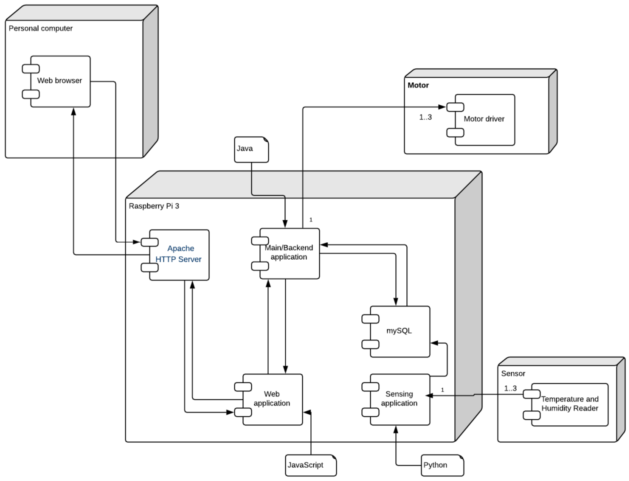

Fig. 3. Deployment diagram.

For the hardware implementation of the proposed solution, the basic schema in Fig. 4 is followed. The system architecture is made of standard RP3, three DHT11 temperature and humidity sensors, three Bipolar NEMA stepper motors and three DRV8825 stepper motor drivers. The implementation is adapted to the already installed heating/cooling unit previously mentioned.

Each DHT11 temperature and humidity sensor is installed in separate rooms. Because we aim for cheap solution, we used wired sensors instead of wireless sensors. The stepper motors and the motor drivers are installed on the existing system's manual dampers, providing us with automatic and remote control for the airflow. The RP3 is hard-wired with the existing thermostat unit which enables turning on/off on the heating/cooling unit.

A. *Raspberry Pi 3 Model B+*

The Raspberry Pi is a series of small single board computers, used for teaching basic computer science such as robotics. This version of RP3 includes dual-band 2.4/5GHz 802.11ac Wi-Fi and three times faster gigabit Ethernet. It has 1.4GHz 64-bit quad-core processor, which can hit higher clock frequencies, and more accurately monitor and control the temperature of the chip. The Bluetooth 4.2 that it has, is a faster gigabit Ethernet. One disadvantage of this new version is the fact that it uses substantially more power than its predecessor.

B. *DHT11 Temperature and Humidity Sensor*

This device measures temperature with the help of NTC thermistor or negative temperature coefficient thermistor [12]. These thermistors are usually made with semiconductors, ceramic and polymers. The resistance of the device is inversely proportional with the temperature and follows a hyperbolic curve. Temperature using NTC often found out Steinhart Hart equation.

The humidity is sensed using a moisture dependent resistor. It has two electrodes and in between them there exist a moisture holding substrate which holds moisture. The conductance and hence resistance changes with changing humidity. The components of this sensor are shown in Fig. 5. Both these temperatures and humidity changes are processed by an IC placed on the other side of the board. It calculates the values of both and can transmit those values to a microcontroller using only a single data line.

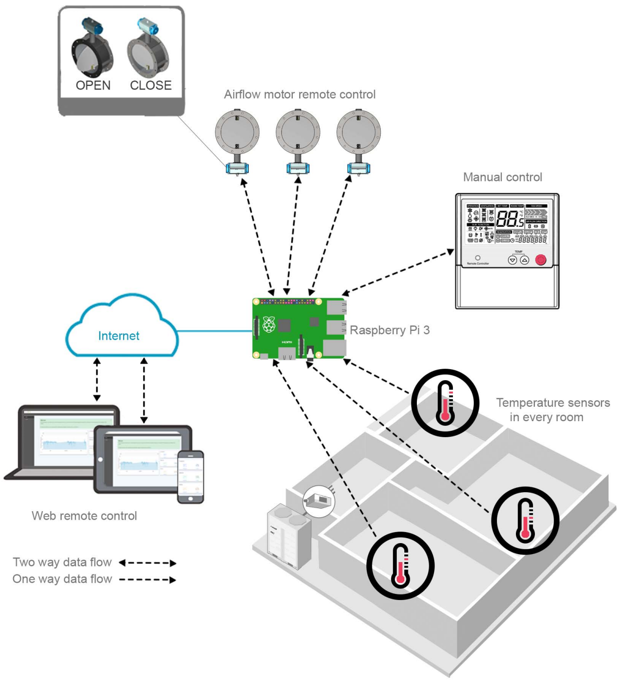

Fig. 4. Visual representation of the system's architecture.

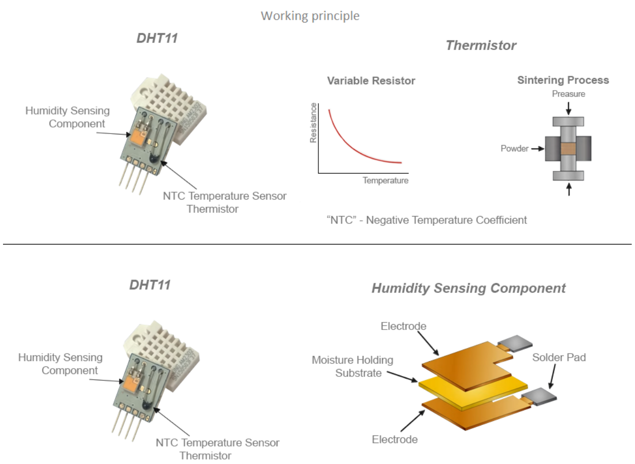

Fig. 5. DHT11 sensors and their components [13].

C. DRV8825 Stepper Motor Driver

This micro stepping bipolar stepper motor driver [14] features adjustable current limiting, over-temperature and over-current protection, and six micro-step resolutions. It can deliver up to 1.5A per phase and operates from 8.2V to 45V. Also, only one bipolar stepper motor can be controlled at up to 2.2A output current per coil.

IV. Software Implementation

In this section the software used for the purpose of the working system is being described.

A. Sensing application

Python application was created for the temperature and humidity readings. Since the DHT11 temperature and humidity sensors require careful timing to grab data, we encountered inaccuracy of the readings because of the long distance to the RP3. With some tweaks in the existing DHT11 driver's library written in Python, we calibrated the transmitting data timings. This modified library is used in the Sensing application for reading the temperature and humidity on 10 second intervals. The application is connected to MySQL database for storing the data measured by each sensor.

B. RP3 Main (Backend) application

For the purpose of integrating our solution to the existing unit, knowing the exact power state of the system was mandatory, and was obtained by identifying the ground pins on the existing thermostat unit and the two pins from the button for turning on/off the heating/cooling system. We soldered wires on the ground and on/off button pins and connected them with the RP3. In other words, the main application became able to monitor changes not only made by the user from the web-application (Fig. 6 and Fig. 7), but also when the changes are manually made from the controlling unit itself. Another purpose of this application is serving content in real time to the Web application discussed in the section below. Pi4j library is used for controlling the RP3 general purpose input/output pins. Integration of the zoning was made possible by installing the bipolar stepper motors on the existing manual damper units and controlling them with the cheap DRV8825 stepper drivers over the RP3 Main application. With full remote control over the airflow to the rooms, we were able to make different zones of the apartment heated or cooled separately. Remote access to the web interface is enabled using the Apache2 web server, deployed and configured on the RP3, providing access to our front-end application.

C. Database

MySQL database is connected to the Sensing application for storing the data measured by each sensor in the living room, kitchen and the bedroom respectively. Date and time are stored in the same database table for each reading. The data is updated only when the latest read temperature for the corresponding sensor differs from the previously stored temperature of 1 Celsius degree. Same as the temperature readings, the power state of the system is stored in the database, but from the Main application itself. The current open/close states for the motor dampers are also stored in the existing database and can be operated from the provided Web application.

D. *Web application*

The web-application has an organized layout with great visuals and provides users with helpful data summary. On the main screen shown in Fig. 6, we provide visual data representation of the collected temperature readings for each room separately and real time temperature and humidity.

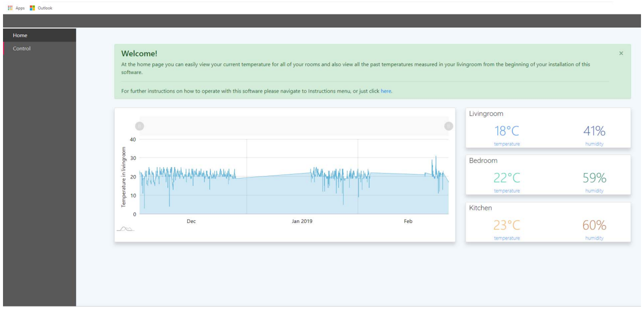

Fig. 6. Home interface for visual representation of the temperature and humidity.

On the left side there is a global menu which provides access to the control options for the apartment. In the control view in Fig. 7, there are multiple sections for adjusting the temperature, either globally or room by room. Another option we provide is the automated mode, where all the zones can be set to different temperatures. With this mode on, the system cares about the airflow, changing the on/off states for the dumpers and the heating/cooling unit. Besides, manual changes over the dampers are still an option, but are done remotely. On top of this, there is an option to set the desired temperature of the rooms before arriving home, using one's phone or computer simply by accessing the web application.

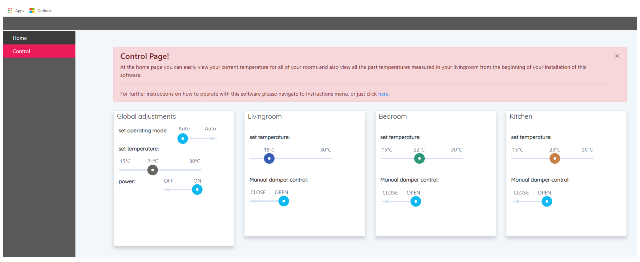

Fig. 7. Control panel for adjusting temperature and damper airflow.

V. CONCLUSION

In this paper, we described in detail the process of development an indoor temperature regulation system based on IoT. Our paper has two main contributions: (1) to remotely regulate the temperature in a condominium-based apartment; and (2) to provide apartment temperature zoning in order to reduce electricity consumption. We managed to show that by combining off-the-shelf hardware components and embedded software, a cheap and contemporary solution can be made. For the future work, we intend to implement a model that will reduce energy spending within the system, like data prediction to lower the number of transmissions within the IoT system [15], or data compression [16]. Other improvement we intend to implement is to replace the wired sensors with wireless.

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