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An Efficient System for Reducing the Power Consumption in Offices Using the Internet of Things

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Abstract

Nowadays, Electricity energy is considered the lifeblood of many companies and industrial institutions. Most of these companies and industrial institutions are suffering from the high cost of the electricity bills because of the large amount of power they consumed per day. Thus, many of the researches are now focusing on how to eliminate the power usage in order to reduce the cost of electricity bills. This issue become significant in the current era. Fortunately, in this era, we are witnessing a revolution in the Internet of Things field, which can provide various solutions for reducing the power consumption. These solutions are based on sensing modules, Artificial Intelligence, and Deep Learning. Any IOT system that attempts to reduce the power wastage must take in consideration achieving a balance between the power conservation and the user satisfaction. This paper contributes the following; first, it proposes an intelligent IOT system for offices that reduces the total power cost by 40% based on the Lecture Time-Table (LTT). The LTT is the instructor's weekly load (i.e. the LTT shows how many classes does the instructor have per week and the number of hours for each class). Second, it achieves a balance between the power conservation and the user satisfaction by allowing manual controlling of appliances (via voice commands) and auto controlling of appliances (based on the LTT). Third, it achieves a balance between the user satisfaction and the power conservation based on the percentage of the overlapped time intervals of the LTTs. Fourth; it eliminates the

use of sound sensors by developing a java program that is capable of capturing and handling the human voice. We built the baseline system, and then we compared the results from the baseline system with the results from our proposed IOT system. Our results showed that the proposed system saved about 40% of the power cost.

Keywords: *Internet of Things, power management, Lecture-Time-Table, event scheduling, user satisfaction.*

1 Introduction

Many of the industrial and commercial institutions are currently suffering from the high cost of power consumption because of the massive number of appliances used by their institutions. These appliances include Pc's, air conditions, and heating system units. These appliances consume a vast amount of electricity. It has been recorded that buildings consume from 20%-40% of the total energy [1][2]. The energy consumption is increased over time, whereas the power sources are limited and may not be enough to meet the demand [3]. Thus, there is a need for efficient approaches to reduce the energy drain by eliminating the power consumption. One of the techniques used to eliminate the power consumption is the Internet of Things (IOT). Internet of Things (IOT) can be defined in various contexts subject to their needs. In [4], the authors defined IOT as a set of objects that can be monitored and controlled through a network such as the Internet. Basically, an IOT system is composed of four modules, namely Data Gathering Module (DGM) or the sensing module, which uses various types of sensors, Data Processing Module (DPM), and the Communication Module (CM). Besides, the IOT system includes things or objects to be controlled, such as building's appliances (e.g., Air Condition (AC), fans, heating and cooling systems, etc.). Next is a survey of the recent work carried out in the field of power conservation using the IOT.

Most of the countries around the world are developing projects for reducing power wastage. Examples of such projects are the works carried out in [5] [6]. In [7], the authors investigated using eQUEST energy simulator in order to simulate the energy consumption in a university library. They also proposed to control the appliances in a university based on weather condition. In [8], the authors proposed to use motion sensors in order to control appliances such as the Air Condition (AC) in a university campus. In [9] the authors suggested to save power in a university by using the Building energy Management System (BMS). In [10] the authors proposed an IOT system for power consumption based on the student attendance using two types of camera namely thermal and HPD cameras. For example, suppose that we have students of the same level distributed in three classes, and that each class contains 30 students. Now, suppose that in winter most of the students were absents. In this case, instead of switching the AC in three classes, the IOT system sends a message that propose to join all students in the three classes into one class where the AC is turned on and it switches off the AC in the other two classes based on the occupancy rate. In [11], the author proposed to control the office’s appliances (e.g. the AC and Fan) automatically based on human occupancy. The authors used various sensors such as temperature sensor and the Pyro-electric InfraRed (PIR) sensors. In [12], the authors proposed a real time IOT power management system. In their system, they used the cloud in order to provide a secure appliances monitoring and controlling.

In this paper, most of the surveyed papers attempted to reduce the power consumption in a university campus based on the human occupancy in the class rooms and no attention were given to the instructor’s office. To the best of our knowledge, no previous work attempted to reduce the power consumption in the instructor’s office. Thus, the research question is how can we efficiently eliminate the power consumption in the instructor’s office while achieving a balance between the user satisfaction and the power consumption?

The objectives of our research are as follows; 1) Develop an IOT system which is capable of eliminating the power consumption by auto-controlling the office’s appliances based on the Lecture Time-Table (LTT). 2) Achieves a balance between the user satisfaction and the power conservation by allowing the user to control the office’s appliances manually via sound commands as an alternative to the motion sensors that are used to detect the user motion and thus control the appliances based on these sensors. This will reduce the total cost of the proposed IOT system. Our research methodology is as follows; we measured the cost of the consumed power for the year 2019 in winter season. We focused on calculating the cost of the consumed power for the electric heaters, and we considered these calculations as the results of our baseline system. In the next year (2020), we calculated the cost of the consumed power for the electric heaters using our proposed system. Finally, we calculated the ratio between the cost of the saved power resulted from the proposed IOT system and the cost the consumed power resulted from the baseline system.

To the best of our knowledge, no previous work proposed to reduce the power consumption in a university campus based on the LTT.

The rest of this paper is organized as follows; Section 2 describes the related work. Section 3 describes the proposed IOT system. Section 4 describes the experiments and the evaluation of the proposed IOT system. Section 5 describes the system limitations. Section 6 is a future research direction section. Section 7 describes the conclusion and future works.

2 Related Work

As it is mentioned previously in section 1, appliances such as the ceramic heaters consume a tremendous amount of power. Thus there is a need for an efficient and smart IOT system for optimizing the power. To tackle this problem and reduce the high cost of electricity bills, many researchers proposed various IOT techniques and frameworks. In this context, in [13], the authors monitored the cooling and heating systems in a building for various periods of time and they found that the cooling system consumed twice the energy than the heating system. Besides, they found that the power consumption of the heating systems is affected by the occupancy rate in the buildings during office hours. This is because of the body temperature, which increases the total temperature in the building and, as a result, the system switches the heating system (e.g., AC) off.

Home Automation (HA) is a smart technology that aims to convert a passive home into an active home via the integration of hardware and software to achieve a high level of civilization, comfort, and low energy cost. The home automation systems include; sensors for gathering information from the environment. A processor for performing data processing/analysis. Actuators that translate the actions into commands and then execute them, and a database for saving the gathered data and the results from the data analysis [14]. Some of the home appliances, as well as the office appliances, consume huge electricity, especially the electric water heaters and the coffee maker machines [15]. Thus, one of the significant roles of IOT is to eliminate electricity wastage [16]. In fact, when designing an IOT system for power conservation, we must take into consideration two crucial issues, namely the power conservation issue and the user satisfaction issue. Achieving a balance between power conservation and user satisfaction is a challenge [17]. In [18], the authors proposed an IOT system for reducing the power consumption by controlling appliances such as the Heating Ventilation and the Air Condition (HVAC) based on weather similarity. The proposed system saved $700 within a month period. In [19], the authors proposed building an IOT architecture for eliminating the power usage in a university campus based on motion sensors and their system saved 2628.29Rs per year. They evaluated their system by comparing the power consumption when using and without using their proposed system. In [20], the authors proposed an IOT system for reducing the power consumption based on motion sensors, humidity sensor, temperature sensor and occupant sensor. Their system saved 11.3% of electricity. In [21], the authors proposed an IOT system based on motion sensor, humidity sensor and temperature sensor. The proposed system saved 20%-25% of energy.

Based on the above literature, we note that most of the previous work focused on solving the problem of power conservation based on using sensors. Besides, the percentage of saving power is between 20%-25%. Our contribution is a smart IOT system that efficiently reduces the power consumption in a university campus based on the LTT and achieves a balance between the user comfort (user satisfaction) and the power conservation (reducing the electricity bill cost). Our proposed system saved 40% of the power consumption compared with the previous work proposed in [20][21]. The proposed IOT system monitors appliances such as the lighting system, the ceramic tube heater, or simply, the electronic heater, and the coffee maker in a university campus and controls them using an intelligent program. The proposed IOT system reduces the power consumption based on the timetable schedule of the lectures. Besides, it fulfils user satisfaction by allowing him to control his office appliances using sound commands. To the best of our knowledge, no previous work proposed reducing the power consumption based on the timetable schedule of the lectures (LTT). The proposed system is tested on a university campus. Various appliances such as the coffee makers, lighting, and electric heaters are controlled automatically (using the timetable schedule of the lectures) and manually via sound commands to fulfil user satisfaction.

3 The Proposed IOT System for Office Appliances Controlling (OAC)

3.1 The System Architecture and the Communication Module

In this section, we describe the proposed IOT system. The proposed system consists of a collection of hardware and software, as illustrated in Fig. 1. The hardware module includes a microcontroller (Arduino Uno), which is connected to three relays of type Songle Relay (SRD). The relay acts as a switch. It can switch to high voltage using low power circuits. The SRD relay has three pins (IN, GND and VCC).

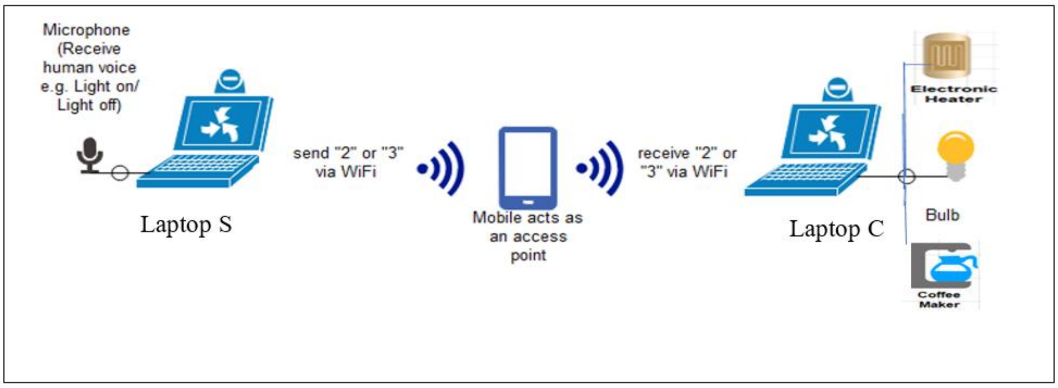

Figure 1. The system architecture and the communication module

The first relay is connected to a bulb (220 V); the second relay is connected to an electronic heater, and the third relay is connected to a coffee maker machine. The "IN" pin of the first relay is connected to pin three on the microcontroller to switch the relay on /off and thus turn the light on/off with respect to the voice command. All appliances are working on 220 voltage. The IN pins of the two other relays are connected to the pins 5 and 6 on the microcontroller to switch the coffee maker machine and the electric heater on/off. The GND pin is the ground pin, and the VCC pin is used as the regulated DC supply voltage. As described in Fig. 2, the three relays are connected to the pins 3, 5, and 6, where they can receive the commands for turning the appliances on/off. The code described in Fig. 2 reads the data from the serial port (In this experiment, we connected the Arduino Uno to port COM 4) and then it checks the encoded message (m) as follows; If m equals 1, then it turns the light on. If m equals 2, then it turns the light off. A Java code is developed to communicate with the serial port to which the Arduino Uno is connected.

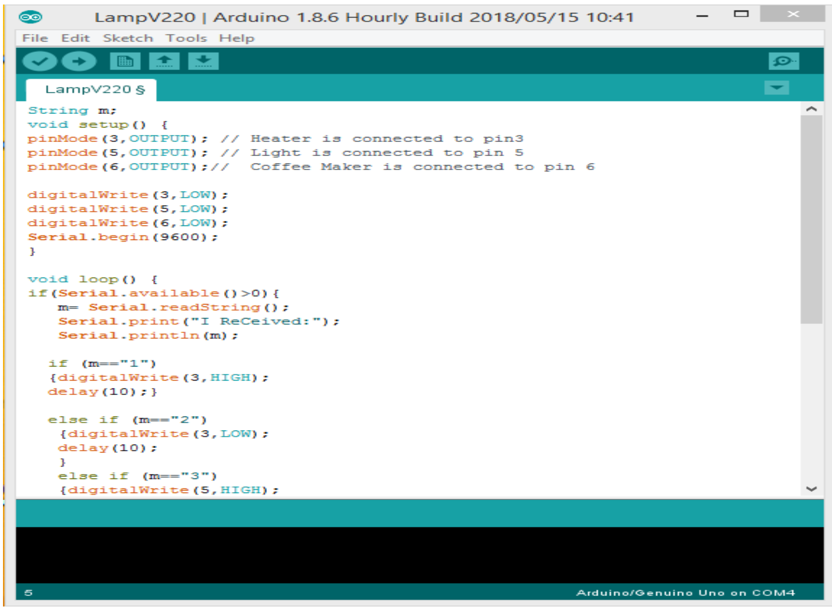

Figure 2. The Arduino Uno code for switching the appliances on/off

In our experiment, we used two laptops (as described in Fig. 1). One of the laptops, say "S", acts as a signal controller. It listens to any sound command (In this paper, six sound commands are issued. Namely; "Light on," "Light off," "Heater on," "Heater off," "Coffee on," and "Coffee off") . The laptop (S) receives the human voice (using java code). Next, it recognizes it, encodes it, and then sends the encoded message to the other laptop, say "C", via an access point (In this paper a mobile is used as an access point). The laptop (C) reads the message, and then it sends it to the serial port to which the microcontroller is connected. Table 1, describes the sound codes.

Table 1. The sound codes

The sound code	The meaning
1	The light is on
2	The light is off
3	The heater is on
4	The heater is off
5	The coffee machine is on
6	The coffee machine is off

To perform this task, client and server programs are built from scratch using java NetBeans and installed on two remote machines. A DatagramPacket and DatagramSocket objects are defined on both sides. The DatagramSockets on both machines listen to port 8080 (For logical port number we can choose any number greater than 1023 and less than 65535). In the first phase of our experiment, the client and the server are tested on the same machine using the loopback address (127.0.0.1), and then the server and the client programs are stored on various laptops.

The sound module (developed in this paper using java) is a real-time module, and it is activated on one of the laptops (laptop "S" in Figure 1). The voice is then encoded into one of the numbers 1-6 (e.g., 2 or 3 in Fig. 1), and then these numbers are sent via the user mobile, which acts as an access point. The benefit of the sound module is that it is used to capture the human presence in the room. Thus, if there is no sound captured for a specific period of time, then this is an indicator that there is nobody in the room, and thus the light is turned off. In this case, the benefit of the proposed IOT system is that it can eliminate the use of sound sensors (as hardware) and replace them with the human sound recognition module (as software). This can reduce the cost and save money. The other benefit is that the proposed system reduces the power wastage and fulfill the user satisfaction.

To eliminate the power wastage during the day, the proposed IOT system is provided with the Lectures Timetable (LTT) for the morning study. This table is prepared by the instructor, and it shows the timetable for the lectures during the week (called the weekly load), as described in Table 2. The LTT is stored in a database called Berkeley DB java edition [22] on the laptop S in order to facilitate the controlling over various office appliances. We choose the Berkeley DB since it is an open-source database, it is entirely written in java, and it provides scalable, high-performance, and efficient services, which makes it suitable for our real-time system.

Table 2. The weekly Lectures Time-Table (LTT)

Day	Course Name	Lecture Time	Lecture Place	Office Hours	Coffee break
Sunday	Special Topics Object Oriented (1) Network Programming	8:00-9:00 AM 9:00-10:00 AM 01:00 – 02:00 PM	9345 9140 9123	11:00-12:00 PM	10:00
Monday	Operating System Data Structure	9:30-:11:00 AM 12:30 – 02:00 PM	9250 9140	11:30: -12:30 PM	11:00
Tuesday	Special Topics Object Oriented (1) Network Programming	8:00-9:00 AM 9:00-10:00 AM 01:00 – 02:00 PM	9345 9140 9123	11:00-12:00 PM	10:00
Wednesday	Operating System Data Structure	9:30-:11:00 AM 12:30 – 02:00 PM	9250 9140	11:30: -12:30 PM	11:00
Thursday	Special Topics Object Oriented (1) Network Programming	8:00-9:00 AM 9:00-10:00 AM 01:00 – 02:00 PM	9345 9140 9123	11:00-12:00 PM	10:00

An alternative to the Berkeley Database is the Java Database Connectivity object (JDBC). However, this option is not suitable for the proposed IOT system since it takes long time to retrieve the data from the database. Berkeley DB stores the data in a hash table as pairs called the key-value pairs. The data described in Table 2 are stored in Berkeley DB as {day, lecture time} pairs.

For example, the pair {“Sunday”, “8:00, 9:00, 9:00, ١٠:00, 1:00, 2:00"} means that the key (K) is "Sunday," and the value (V) is "8:00, 9:00, 9:00, ١٠:00, 1:00, 2:00".

The string value “8:00, 9:00, 9:00, ١٠:00, 1:00, 2:00” is processed on laptop S as follows; first, V is split using the “,” delimiter into the values {8:00}, {9:00}, {9:00}, {10:00}, {1:00} and {2:00}. Then each one of the above values is split into two values namely {hours}, {minutes} using the delimiter ":". Thus, {8:00} is divided into {8} and {0} which represents the hours and minutes. This is done for each lecture’s time in order to take some actions when comparing them with the current time on the laptop S.

Now, suppose that the instructor drinks coffee during the office-break hours (as described in Table 2). For example, on Sunday, Tuesday and Thursday, she/he drinks coffee at 10 O'clock in the morning. Our proposed IOT system is intelligent enough to treat this behavior automatically based on the LTT. Thus, it turns on the coffee-maker machine at 9:55. Therefore, when the instructor finishes his lecture at 10 O'clock and returns to her/his office, she/he finds his coffee ready and thus save time.

As we mentioned earlier in this paper, the main aim is to save power by monitoring and controlling the office appliances in a university campus. The office appliances include the light, the ceramic heater and the coffee-maker machine. We focus on the ceramic heater since it consumes the largest amount of power. The cost of the lighting system will be excluded from our calculations. However, the motivation for controlling the lighting system during the daytime is that we examine our system in winter season where most of the time the sky is cloudy and thus switching the light on in the daytime is necessary because of the room darkness. Although, the controlling of the lighting system save amount of power, we drop it from our calculations and we focus on the ceramic heater since it consumes more power. Controlling the lighting system and the ceramic heater) is carried out based on the LTT as follows; suppose that the instructor turns the light and the ceramic heater on when he entered his office in the morning (e.g. at 7 O’clock) and then at 8 O'clock, he goes to his lecture for one hour (see Table 2). In this case, our proposed system checks the LTT, and thus it turns the light and the ceramic heater off at 8:00, 9:00 and 1:00 O'clock on Sunday, Tuesday and Thursday for one hour (the lecture time) since the instructor is out of his office. It also turns the light and the ceramic heater off at 9:30 and 12:30 for one and half hours (the lecture time) on Monday and Wednesday, and thus, it saves the energy. But, what if the instructor returns to her/his office during the lecture time and he wants to turn the light on? She/he is still able to control the room's light by issuing a voice command such as "Light on." Fig. 3 describes the proposed system before issuing any command (either a voice command or a command that is issued automatically because of the LTT table). Fig. 4, explains how the relays are connected to the Arduino Uno microcontroller. Fig. 5 describes our proposed system when receiving the voice command "Light on."

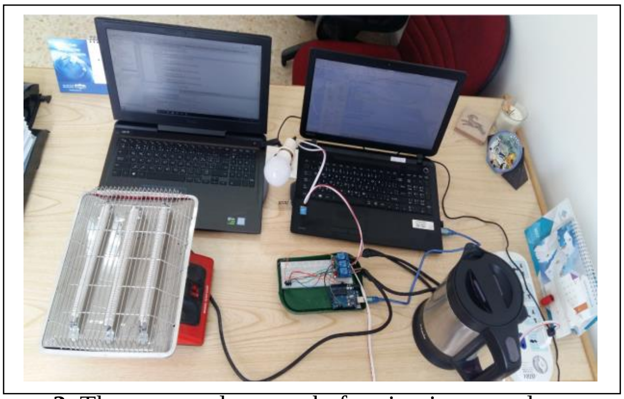

Figure 3. The proposed system before issuing sound commands

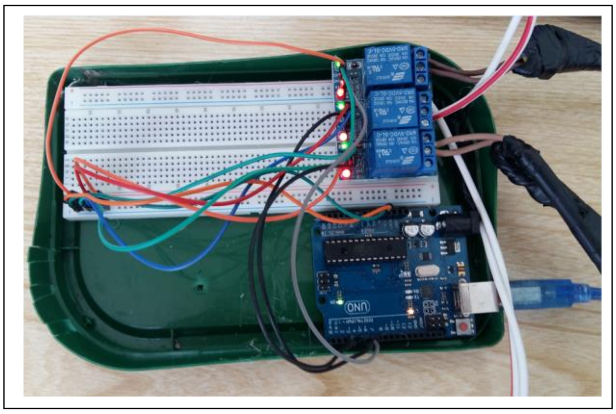

Figure 4. Connecting the relays to Arduino Uno microcontroller

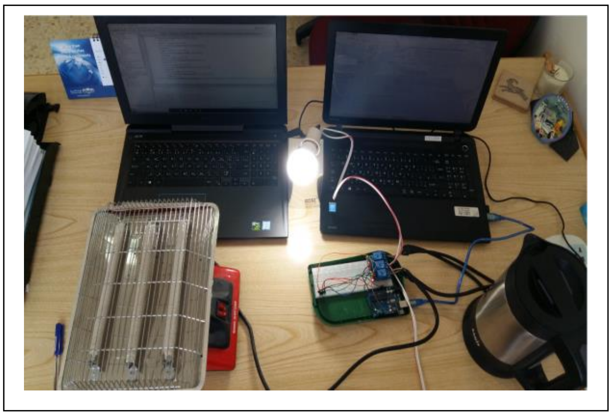

Figure 5. Turn the light on when receiving the voice command “Light on”

Fig. 6, illustrates the proposed system when receiving the voice command "Heater on." Fig. 7, describes the proposed system when it receives the voice command "Coffee on" (see the fog over the heater).

Figure 6. Turn the ceramic heater on when receiving the voice command “Heater on” (see the red bar in the middle)

Figure 7. Turn the coffee maker on when receiving the voice command "Coffee on"

3.2 The Research Methodology

In this section, we describe the research methodology of our proposed IOT system. The research methodology is as follows; we calculate the cost of the power consumption for the ceramic heater during the winter season (year 2019) and the results from this calculation is considered as our baseline system. In the next year (2020), we activate our proposed system and we calculate the power consumption during the winter season. Now, to evaluate our proposed system, we calculate the ratio between the cost of the saved power and the cost of the consumed power resulted from the baseline system.

The following is the pseudo-code for the proposed system. It explains how the proposed system controls the three appliances; namely the light, the coffee maker, and the ceramic heater. The pseudo-code describes the process carried out for specific days (Here, we choose the days Sunday, Tuesday, and Thursday) for clarification. The last if-statement in the pseudo-code is used for controlling the ceramic heater (turns it off) after the end of every working day. Here, we suppose that the leaving time for all employees in a university is at 4:00 PM.

Pseudo code:
Steps on the sender Side (S) and the receiver side (C):

S: Retrieves the Lecture Time-Table (LTT) from the Berkeley DB
S: Retrieves the current Day (D)
S: Searches (D) in the database and retrieves the Lectures time (t1, t2 and t3)
// we suppose that the instructor has 3 lectures per day for example the 1st lecture is at 8:00 //(t1=8) and the 2nd lecture is at 9:00 (t2=9) and the 3rd lecture is at 1:00.
S: Gets the current Time (Ct)
If ((D.equals("Sunday")) || (D.equals("Tuesday")) || (D.equals("Thursday")))
{ *// this part is for reducing the power wastage resulted from the* ***lighting system*** *and the*
// ***ceramic heater***
If ((Ct.hours >= t1) && (Ct.hours <= t1+1) || (Ct.hours >= t2) && (Ct.hours<=t2+1)

|| (Ct.hours >= t3) && (Ct.hours<=t3+1))

Yes:

{

S: Sends the code "2"and "4" to the other laptop (i.e. laptop C).

C: When receiving the numbers "2" and "4", it writes them on its serial port COM4 (the port where the microcontroller is connected).

C: The microcontroller (Arduino Uno) reads the serial port's contents.

C: The Arduino Uno checks the received message m:

If (m =="2") then turn the light off, unless a voice command is received.

If (m =="4") then turn the ceramic heater off unless a voice command is received}

***No**: Receive voice command*

*// this part is for the **coffee maker***

S: Retrieves the Ct and checks the following;

If ((Ct.hours == t2) && (Ct.minutes=55))

***Yes**: turn the coffee maker on by sending the code 5 to C, unless a voice command is received.*

***No**: Receive voice command.*

If (Ct > 4)

If (the light is on) turn it off

If (the ceramic heater is on) turn it off

}

The above pseudo code is briefly described in Fig. 8.

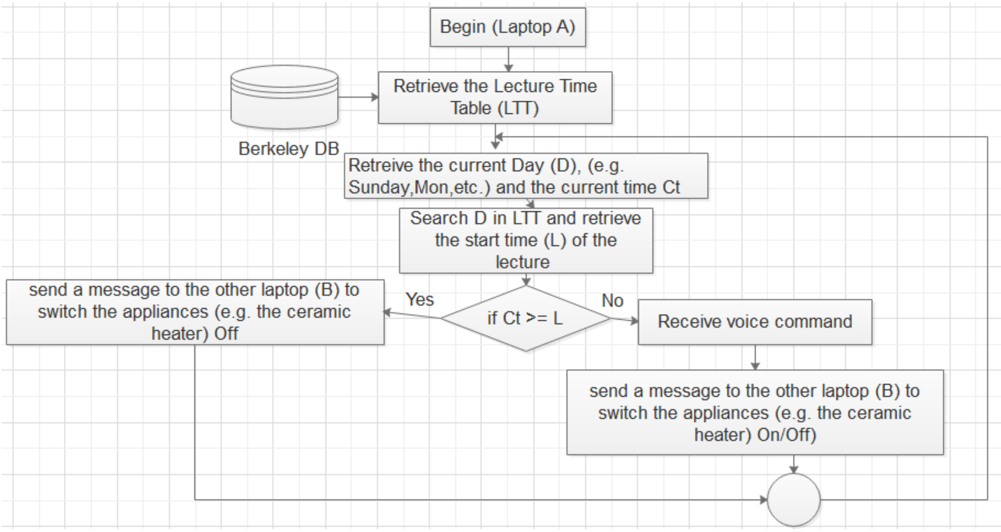

Figure 8. A brief diagram of the proposed system

4 The Experiment and Evaluation

We use Netbeans (Java) as a vehicle to carry out our experiments. Besides, we use two laptops with the following specifications; the first laptop is Intel(R) Core(TM) i7-8750H CPU@ 2.20 GHz, RAM = 32GB while the second laptop is

Intel (R) core (TM)2, Duo CPU T5870 @ 2.00GHz, installed memory (RAM) 2.00GB operating system Windows 7 Ultimate.

To evaluate the proposed IOT system, we compare the results from the baseline system with the results from the proposed IOT system. Table 4 describes the notations used in calculating the power cost for both of the baseline system and the proposed system.

Table 4. The notations used in calculating the power cost

The notation	The meaning
T	The number of hours the heater is on
T_{MONTH}	The number of hours the heater is on in one month
H	The number of hours the heater is on per day
W	The number of working days in the campus
T_{WINTER_SEASON}	The number of hours the heater is on during the winter season
R_{WINTER_SEASON}	The running cost for the heater during the winter season
R_{ALL}	The total running cost for all heaters in all offices.
S_P	The ratio of the saved power
C	The cost of electricity per hour (based on Table 3)
C_S	The cost of the saved power resulted from the proposed IOT system
C_C	The cost of the consumed power resulted from the baseline system
O	The total number of rooms in a university campus
C_P	The consumed power in kW
S	The saved power in kW

4.1 Calculating the Cost of the Power Consumption

In this section, we calculate the cost of the power consumption for the ceramic tube heater. Table 3, describes the cost for each kilowatt per hour (kWh) as it is recorded by the National Electric Power Company of Jordan [23].

Table 3. The Power cost in Fils/kWh in Jordan [23]

Retail Tariff	Tariff Fils/kWh
Bulk Supply Tariff	
JEPCO	
Peak Load (JD/kW/ Month)	2.98
Day Energy (Fils/kWh)	74.82
Night Energy (Fils/kWh)	64.77
Household	
First Block: from 1-160 kWh/Month	33
Second Block: from 161-300 kWh/Month	72
Third Block: from 301-500 kWh/Month	86
Fourth Block: from 501-600 kWh/Month	114
Fifth Block: from 601-750 kWh/Month	158
Sixth Block: from 751-1000 kWh/Month	188
Seventh Block: more than 1000 kWh/Month	265

In Table 3, the JEPCO is the shortcut for the Jordan Electricity Power Company.

Now, to calculate the power cost for the ceramic tube heater, we use equation (1) below:

Running cost (R) = Energy input (kW) x Fils per kWh [24] (1)

Thus, using eq. (1), the running cost of the ceramic tube heater is:

R = 1.8kW x 7.4

= 13.32 penny/hour.

Note that in the above calculations, we use the value 1.8kW as the Energy input since the ceramic heater consumes 1.8kW/hour where the cost is approximately 7.4 penny (Here we use the Day Energy cost which is 74.82 Fils/kWh as described in Table 3).

4.2 The Baseline System

In Jordan, the winter season is about five months starting from December and ending with April. In the previous year and during winter, we used the ceramic tube heater and counted (T) from 02-Dec-2018 until 02-May-2019. The T value is calculated as follows;

Each day, the ceramic heater was turned on from 9:00 AM – 3:00 PM, except for Friday and Saturday. Thus, the heater was turned on for 6 hours per day and therefore,

$$T_{MONTH} = 4 * H * W \quad (2)$$

$$= 4 * 6 * 5$$

$$= 120 \text{ hours/month}$$

Since we observe the ceramic heater for five months (from 02-Dec-2018 to 02-May-2019), then

T_{WINTER_SEASON} = 120 *5

= 600 hours/winter_season

Thus, the consumed power C_P during winter season for one office is as follows;

$$C_P = T_{WINTER\_SEASON} \text{ x power consumed/hour} \quad (3)$$

$$= 600 \text{ x } 1.8$$

$$= 1080 \text{ kW}$$

For all offices, C_P = 1080 x 334

= 360720 kW

Calculating the total cost for power consumption for one office, we have:

$$R_{WINTER\_SEASON} = C * T_{WINTER\_SEASON} \quad (4)$$
$$= (1.8 \times 7.4) * 600$$
$$= 7992 \text{ penny}$$
$$= 79.92 \text{ JD}$$

Since there are 334 office on the campus, the total cost of the consumed power in all offices is calculated as follows;

$$R_{ALL} = R_{WINTER\_SEASON \text{ for one office}} * O \quad (5)$$
$$= 79.92 * 334$$
$$= 26693.28 \text{ JD}$$

The above calculations (described in eq. 5) represent the power cost of the ceramic heater during winter and it represents the power cost resulted from our baseline system.

4.3 Running and Evaluating the Proposed IOT System

In the next year, we activate our proposed IOT system from 02-Dec-2019 until 02-Apr-2020. This year, we calculate the cost of the consumed power of the ceramic heater for only four months instead of five months as in the previous year. This is because of the coronavirus, which stops the teaching in the university starting from April until now. However, if we recalculate the number of hours the heater was on for four months instead of five months for the baseline system, we will get:

$$TWINTER\_SEASON = 120 * 4$$
$$= 480 \text{ hours/winter\_season}$$

In this case, the CP for all offices = 480 x1.8 x 334

= 288576 kW

Substituting 480 hours in Eq. 4, the $R_{WINTER\_SEASON} =$ 63.936 JD. Therefore, R_{ALL} (C_C) = 21355 JD.

Now, we calculate the cost of the saved power for the proposed system for four months as follows:

1. Our system switches the heater off when the instructor goes to her/his lecture.
2. The weekly load (L) for each instructor is 12 hours/week.
3. $T_{MONTH} = L * 4$

   $= 12 * 4$

   $= 48$ hours/month

Thus, our system will turn the heater off for 48 hours/month for each office. In this case,

S (for one office/month) = 48 x 1.8

= 86.4 kW.

and the S (for one office for four months) = 48 x 1.8 x 4

= 345.6 kW.

Thus, the S for all offices = 345.6 x 334

= 115430.4 kW.

4. The ratio between the saved power S and the consumed power C_P (in kW) is as follows;

   $= S/C_P$

   = 115430.4 / 288576 kW

   = 0.4 kW

   = 40% kW.

5. The cost of the saved power C_S for the winter season for one office (see Eq. 5) is:

   $R_{WINTER\_SEASON \text{ for one office}}$ = (1.8 x 7.4) * 48 * 4

   = 2557.4 penny

   =25.57 JD

Thus, the cost of the saved power C_S in all offices:

R_{ALL} (S) = 25.57 * 334

= 8541.85 JD

Therefore, the ratio of the saved power (S_P) is calculated as follows;

$$S_P = C_S / C_C \quad (6)$$

$$\approx 8542/21355$$
$$\approx 0.4$$
$$\approx 40\%$$

Note that during the lecture time, the system turns the heaters off automatically, and it does not allow them to operate until the instructor returns to his/her office and issues a sound command by which she/he orders the heater to turn itself on. Since the instructors have different lecture times, the time on which the heaters are turned on/off is varied from one instructor to another based on the input lecture-time schedule. Note that our calculation is based on the weekly load for each instructor (L), but not on her/his schedule. Table 5, describes the differences between our proposed system and the state-of-the-art. Since the authors in the previous work used different metrics for measuring the quantity of the saved power [18][19][20][21], we compare our work with the most recent and most closely related to our work.

Table 5. Comparison between the state-of-the-art and the proposed system

Paper reference	Technique	Saved power
[20] (2018)	Semantic framework for the user behavior.	11.3%
[21] (2019)	Sensor-based. (Studied the effect of outdoor temperature on the power consumption)	20% - 25%
Our proposed system (OAC)	Time-based. (Develop an intelligent programs for controlling the office appliances based on the LTT	40%

As described in Table 5, our proposed system saved more power than the other related work.

5 The System Limitations

The proposed system is limited by the scope of the communication module (i.e., the WiFi protocol). However, the system can be upgraded to be used via the cloud (e.g. using a mobile and the firebase platform). Also, the proposed system can be enhanced with Google Assistant to eliminate the noise in the captured sound. Another issue to be taken into consideration is security;

In IOT systems, security and privacy are essential while the data is exchanged through the Internet at any time. The most common communication protocol for data exchange is the Message Queuing Telemetry Transport Protocol (MQTT). This protocol is evaluated for various types of attacks [25].

However, to secure the data of our system, we may use the encryption methods proposed in [26] [27][28][29]. Another approach for securing data is the method proposed in [30]. In this method, the Biometric authentication is integrated with the IOT technology to enhance the user identification and authentication. Another choice is to use the Image Cryptology proposed in [31], BlockChain technique [32] or detection techniques [33].

6 Future Research Direction

As we mentioned earlier in this paper one of the aims is to achieve a balance between the user satisfaction and the power consumption. As an attempt to achieve the above goal this paper proposed manual controlling via voice commands and auto controlling using the LTT. In this context, we propose another method for achieving this goal. Suppose that in a university campus each 20 office are located in one area (we call it a block). In this case, a university may contain a number of blocks Bn = total no. of offices/20 = 334/20 ≈ 17 blocks. In winter, the instructors are satisfied if the block, in which their offices are located, is worm enough. During the lectures time our system switches the ceramic heaters off, thus it is possible that most of the ceramic heaters are switched off in a specific block (B) in a specific time (T) based on the LTT. This will decrease the block's temperature and thus decrease the user satisfaction level. To overcome this problem, we propose to manage the block's temperature based on calculating the LTTs intersected-intervals as follows; Suppose that we have the lectures set L= {LTT(1), LTT(2), LTT(3)... LTT(n)} in the block B, where LTT(i) represents the lecture timetable of the instructor (i). Table 5, represents sample of the LTTs for six instructors in block B.

Table 5. The Lecture Time Table (LTT) for multiple instructors

Instructor ID	LTT	Instructor ID	LTT
1	Sunday {8:00-9:00, 10:00-11:00, 01:2:00} Monday {09:30-11:00, 11:00-12:30} Tuesday { 8:00-9:00, 10:00-11:00, 01:2:00} Wednesday {09:30-11:00, 11:00-12:30} Thursday {8:00-9:00, 10:00-	2	Sunday {8:00-9:00, 10:00-11:00, 01:2:00} Monday {11:00-12:30, 12:30-02:00} Tuesday { 8:00-9:00, 10:00-11:00, 01:2:00} Wednesday {11:00-12:30, 12:30-02:00} Thursday {8:00-9:00, 10:00-

	11:00, 01:2:00}		11:00, 01:2:00}
3	Sunday {9:00-10:00, 11:00-12:00, 01:2:00} Monday {11:00-12:30, 12:30-02:00} Tuesday {9:00-10:00, 11:00-12:00, 01:2:00} Wednesday {11:00-12:30, 12:30-02:00} Thursday {9:00-10:00, 11:00-12:00, 01:2:00}	4	Sunday {8:00-9:00, 10:00-11:00, 01:2:00} Monday {8:00-09:30, 09:30-11:00} Tuesday { 8:00-9:00, 10:00-11:00, 01:2:00} Wednesday {8:00-09:30, 09:30-11:00} Thursday {8:00-9:00, 10:00-11:00, 01:2:00}
5	Sunday {8:00-9:00, 10:00-11:00, 01:2:00} Monday {8:00-09:30, 09:30-11:00} Tuesday { 8:00-9:00, 10:00-11:00, 01:2:00} Wednesday {8:00-09:30, 09:30-11:00} Thursday {8:00-9:00, 10:00-11:00, 01:2:00}	6	Sunday {9:00-10:00, 11:00-12:00, 01:2:00} Monday {8:00-09:30, 09:30-11:00} Tuesday {9:00-10:00, 11:00-12:00, 01:2:00} Wednesday {8:00-09:30, 09:30-11:00} Thursday {9:00-10:00, 11:00-12:00, 01:2:00}

As described in Table 5, the LTTs for the instructors 1, 2, 4 and 5 intersect in the days Sunday, Tuesday, and Thursday where the lectures time is {8:00-9:00}, {10:00-11:00} and {01:2:00}. Besides, the LTTs for the instructors 2 and 3 intersect in Monday and Wednesday where the lectures time is {11:00 – 12:30, 12:30-02:00}. In addition, the LTTs for the instructors 3, 6 intersect in Sunday, Tuesday, and Thursday where the lectures time is {9:00-10:00}, {11:00-12:00} and {01:00-02:00}. Thus, in Sunday, Tuesday, and Thursday, the ceramic heaters will be switched off in the offices 1, 2, 4 and 5 for a specific time as well as the offices 2 and 3, and 3 and 6, and this may decrease the block’s temperature. Given the above scenario, we may define the percentage of the overlapped time intervals of the LTTs per day (ƛ) where,

$$ƛ = O / m \quad (7)$$

Where,

O: is the number of overlapped time intervals of the LTTs in one day

m: is the total number of lectures.

And thus,

$$ƛ = \sum(LTT_{(1)} \cap LTT_{(2)} \cap LTT_{(3)} \cap .. LTT_{(m)}) / m \quad (8)$$

$$ƛ = \sum (t_{11}, t_{12}, .. t_{1n}) \cap (t_{21}, t_{22}, .., t_{2n}) \cap .. (t_{m1}, t_{m2}, .. t_{mm}) / m \quad (9)$$

In the above equation, t_{11}, t_{12}, .. t_{mm} represent the lectures time as an interval (e.g. t_{11}= 9:00-10:00). In this case, the first interval t_{11} is checked if it is overlapped with the other intervals from other LTTs (i.e. $t_{11} \cap t_{21}$, $t_{11} \cap t_{22}$ and so on). Note that the result of $t_{11} \cap t_{21}$ can be either 1 or 0 and thus, if the result is 1, then the O value (see Eq. 6) will be incremented by 1. Now, given that we have 334 instructors in a university and that each 20 instructors are located in one block (B), and that each instructor have 12 lectures (the weekly load), then we have 20 ×12 = 240 lectures. Now, suppose that 120 lectures are overlapped in one block (B) at a specific time, then:

$$\lambda = 120/240$$
$$= 12/24$$
$$= 0.5.$$

This means half of the instructors (50%) will leave their offices giving their lectures at the overlapped time and thus their appliances (the ceramic heaters) will be turned off. This may decrease the temperature of the block in which the 20 offices are located. Thus, there is a need to manage this situation and keep the area worm enough in order to achieve the user satisfaction. Obviously this issue can be controlled based on the λ value. For example, one of the policies is that if λ value is ≥ 0.8 (i.e. more than 80% of the instructors are out of their offices) then 0.5 or (50%) of the total appliances must be switched on even if the instructors out of their offices in order to keep the area worm and thus achieve the user satisfaction. Achieving a balance between the user satisfaction and the power conservation is carried out using λ, since the large values of λ decrease the power consumption (less heaters will be switched on), but this will decrease the level of the user satisfaction since the area becomes cool. Thus, we need to set λ to a specific value that makes trade-off between the user satisfaction and the power consumption. However, more research is required in order to study the best action to be taken (e.g. how many ceramic heater must be turned on) based on λ value. Abusukhon in [34] proposed a novel IOT prototype which achieves a balance between the user satisfaction and the power consumption and proposed many of the research problems which needs further research in this context.

7 Conclusion and Future Work

In this paper, we proposed an intelligent IOT system that achieved a balance between user satisfaction and power conservation based on the Lectures Timetable (LTT) and a sound module built in java. The proposed IOT system is tested for the offices located at a university campus. In the proposed system, the instructors can manage the power in their offices with respect to their lectures schedule. To the best of our knowledge, no previous work investigated reducing the power wastage based on the lectures timetable (LTT). Our contributions are:

1) The proposed system reduced the power wastage by 40% based on the LTT (see Eq. 6). 2) The proposed system achieved a balance between the user satisfaction and power consumption by allowing manual controlling of appliances via voice commands and auto controlling of appliances based on the LTT that is provided by the instructor. Besides, the proposed system achieved a balance between the user satisfaction and the power conservation based on the percentage of the overlapped time intervals of the LTTs per day (ƛ). 3) The proposed system eliminated the use of the sound sensors by using a java program for capturing and handling the human voice. In future, we intend to expand the proposed system. For example, the communication module will be expanded to cover wide areas via the cloud and thus home appliances can be managed from a far distance. Besides, more techniques will be developed for recognizing the human behavior and thus provides an efficient balance between user satisfaction and power conservation. Finally, our system can work indoor and can be used in somehow with the technique proposed in [35] which manage the power based on the user location and the work proposed in [36]. However, a new technique of localization for outdoor nodes which does not require GPS devices is proposed in [37] and can also be useful for future work.

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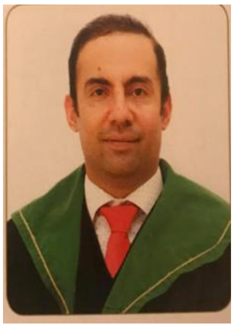

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