Design of a Fully Wireless Indoor Smart Energy Saving and Monitoring System

Li Woon Koay, Yasir Hashim

Abstract: The wireless indoor smart technology has changed rapidly and improved daily living. Humans will continue to enjoy comfortable and convenient lives with the support of the latest technology. The proposed Smart Energy Saving and Monitoring System (SESMS) was designed and developed to control the operations of indoor electrical appliances, especially in offices. SESMS is wireless and fully automated, and it reduces power consumption, particularly in high power consuming sectors, such as commercial and industrial areas. SESMS includes a monitoring system that can analyze the data collected from various conditions, thereby avoiding electricity wastage. The interface of the Monitoring Control System was designed to collect data easily and to show the information clearly to users. The collected data will display clearly and automatically in Microsoft Excel. The interface of the monitoring system indicates the status of every office according to the data collected.

Index Terms: Keywords: Fully Automated, Monitoring System, Smart Energy Saving System, Wireless.

I. INTRODUCTION

Technology has given way to useful inventions and has brought comfort and fulfilled the demands of daily living [11][5]However, these advancements have increased power consumption. To address this issue, technology plays an important role in generating the power needs of domestic and commercial users. Strong correlation is shown between increased wealth and increased energy consumption. Hence, to achieve the target, intention, or policy of reducing energy demand, measures are conducted at a global level. Increasing power usage has given way to labor intensive activities to reduce energy, but such activities will be effective in the long term.

Greenhouse effect has showed a big impact of destroying atmosphere slowly due to consume high energy consumption imprudently. One of the reasons of power consumption is to enhance life by raising the quality of living through using facilities more than necessary. Technologies providing opportunities for home energy management have been on the rise in recent years. A number of researchers and engineers have developed ubiquitous indoor network models. The ubiquitous indoor network models bring out the potential of smart home technology to deliver the benefits such as comfortable, convenience and even cost-saving in bills.

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Therefore, a smart energy saving system is proposed to address this issue. The proposed system is a reliable wireless indoor Smart Energy Saving and Monitoring System (SESMS) that solves the problem permanently. The smart energy saving system is fully wireless and automated, and it functions well without any remote control. Moreover, the system includes a monitoring system to show how much power has been used and to analyze how much power has been saved daily. This system is designed for the office area. Using a simple concept, the proposed system focuses on saving energy in every electrical appliance in the entire office area and is a better option for reliability than using a smart home system designed for homes and not offices.

II. LITERATURE REVIEW

The demand for smart home technology has been raised by users and motivated researchers to develop this technology. Ford and his colleagues identified opportunities for energy savings (both behavioral and operational) as well as load shifting across most product categories, however, in many instances other potential benefits related to convenience, comfort, or security may limit the realization of savings. This is due to lack of information related to energy being collected and presented to users, as well as lack of understanding of how users may interact with the additional information and control provided. Ford et al. recommends that users should be educated on ways to interact with technology at home and in the grid in a fully integrated smart home environment. Meanwhile, other related research stated that proper management of energy is necessary to address and manage issues of energy supply, demand, and pricing needs to support the economy [1]The management should be capable of monitoring electrical peak load effectively by using metering, display and communication layers with the utility. Nojeong et al. **[9]** proposed an algorithm of distributed energy-efficient deployment is proposed through an algorithm for mobile sensors and intelligent devices to form an Ambient intelligent network. Their algorithm is evaluated in terms of several parameters to exhibit performance. These algorithms employ a synergistic combination of cluster structuring and a peer-to-peer deployment scheme. An energy-efficient deployment algorithm based on Voronoi diagrams is also proposed Performance of these algorithms is evaluated in terms of coverage, uniformity, and time and distance traveled until the algorithm converges. Our algorithms are shown to exhibit excellent performance A smart energy saving system in the housing area or Home Automation System (HAS) enables power consumption

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management. According to Pandya(Bhavik Pandya, Mar, 2016), the smartphone interacts with the Arduino BT board to operate appliances in the housing area by running an Android application using a BT module to transfer signals. Users could then give a command via voice command sensing. Anitha [12] stated that a user-friendly interface, scalability and cost effectively could be achieved by the HAS when using an Android device with Wi-Fi as communication protocol and Raspberry Pi as server system interfaced with a relay circuit board. This method could control home appliances efficiently. Modern equipment allows the smart system to achieve higher accuracy of data analysis and ease of use. According to Tseng,[13] the concepts of motion sensing concept and Internet of Things (IoT) could be applied in smart house monitoring and management. The Zigbee sensor has been used for the interaction of sensors and actuators to achieve convenience, safety, and power-saving in a house. Furthermore, Shanmugam and Santhoshkumar [8] stated that HAS can be modified into a reliable system by controlling indoor appliances through transmitting and receiving radio frequency signals, which is suitable for older persons to use without depending on others.

Lim and Han(Han & Lim,)[6] have proposed new Smart Home Energy Management System (SHMS), which is based on an IEEE802.15.4, actuator components, and the Zigbee sensor network, this new SHMS is improved by a new developed routing protocol e.g. Disjoint Multi-Path based Routing (DMPR). The developed system provides intelligent services for users and can be implemented in a real environment. David and his colleagues(David, Chima, Aronu, & Obinna,)[3] present a low-cost, flexible home control that consists of an environmental monitoring system, which employs Arduino Mega 2560 microcontroller with IP connection via Bluetooth Android apps. However, the proposed system does not provide any protocol to monitor and control the devices in the home environment. According to Thamaraiselvi et al. [7] a server for global usages, such as GSM Technology, is being explored to control home appliances. This system is known as the HAS. The system uses wireless technology and is SMS based to control home appliances remotely and to provide security. In addition, studies are carried out on designing a HAS via Internet activities, such as reading e-mail, to control and monitor appliances. Researchers(S)[10] believe that using the Internet could increase the connectivity of devices and the home automation through the system. According to,[4] Davidoff et al. presented different designs to make dual-income families have more control in their lives. These families often feel out of control due to the complex and rapidly changing logistics that result from integrating and prioritizing work, school, family, and enrichment activities. These principles allow end-user programming systems to deliver the control based on the needs of families.

In this research, a wireless indoor smart energy saving system mainly for the office area rather than for the smart home is proposed. The system monitors the electricity usage of every room in the office and analyses the daily, monthly, and yearly power use. This analysis data record is useful in minimizing power wastage in the working area and checking working hours of every worker.

III. METHODOLOGY/MATERIALS

A. Current Study

According to research study GFK, Germany's largest market research institute, states that smart home technology has potential to lead a number of organization planning to address the market forecast globally. Based on the surveyed, more than 7000 consumers across different markets require the expected technology in lives. The response of consumer to the smart home, five main categories have been explored include security and control, appliances, entertainment and connectivity, energy and lighting, health. This work uses contents analysis to analyses data about the awareness of smart home benefits, the key aspects of delivering smart home technology, and also the greatest impact brings in housing area.

The current study aim is to provide IoT mainly in buildings. The semiconductor maker company Intel Corporation has developed the buildings with intelligence built in and possible to get more accurate data and ultimately, a better decision. In this research aim to apply the technology focus on office area. The implemented system known as Smart Energy Saving and Monitoring System (SESMS), enable to analyses data and monitor the presence of the employee. SESMS reduces the expenses by saving more energy, and deliver the more accurate data and useful information to the consumers. The following sections describe each of these processes in further detail.

B. Smart Energy Saving and Monitoring System Design

The proposed wireless smart energy saving system includes different subsystem parts to form SESMS. Fig. 1 shows the general flow of the whole system. The sensors, relay, and electrical appliances in an office area are connected by a transceiver module through a wireless network. Therefore, all sensors and appliances are controlled by a Microcontroller Unit (MCU) automatically. The MCU then sends the signal received to the monitoring system and analyses the data.

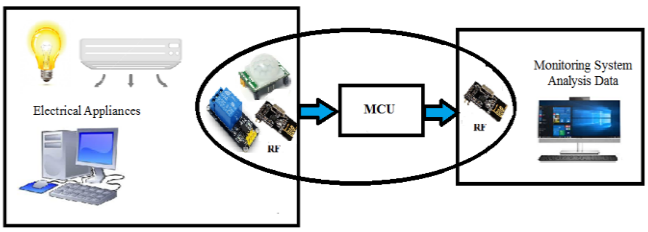

Fig. 1 General flow of SESMS

The proposed SESMS consists of three different subsystems, namely, Detection, Switch Controlled, and Monitoring Controlled System. Fig. 2 shows the Detection System that represents the first operator system in SESMS. In the Detection System, the PIR sensor will detect movements' signals in the office area, and send it to the MCU I. Then the MCU I will send the signal received to the Switch Controlled System through the Transceiver Module I.

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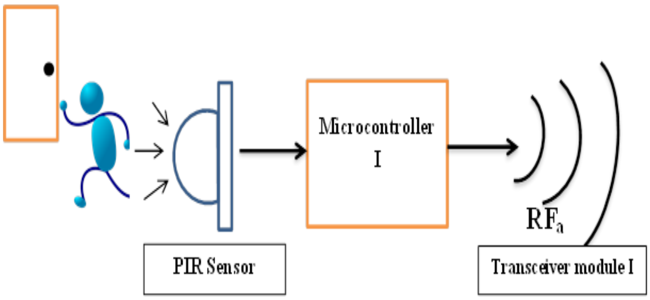

Fig. 2 Detection System

Fig. 3 shows the Switch Controlled System, which controls the electrical appliances in SESMS. The Switch Controlled System receives the signal from the Detection System through transceiver module II. After the signal is received by the MCU II, two operations will follow. First, the system will decide between ON and OFF by activating the relay to control the main switch of the electrical appliances in the office according to the detected signal. Second, the system will send the signal of operations to the Monitoring Controlled System through the same Transceiver Module II.

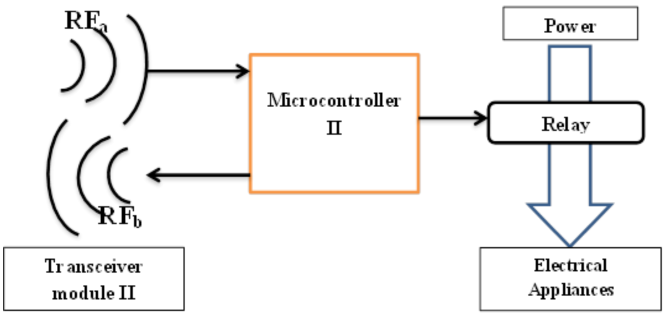

Fig. 3 Switches Controlled System

Fig. 4 presents the third part of the subsystem, the Monitoring Controlled System in SESMS. The Monitoring Controlled System will receive the signal from the Switch Controlled System through the Transceiver Module III. Data from the Switch Controlled System, follow by MCU III will be sent to the Monitoring System for analysis. In this subsystem, collected data will be analyzed and calculated to determine how much energy was saved or used daily. Besides that, the system will display the status of the office area.

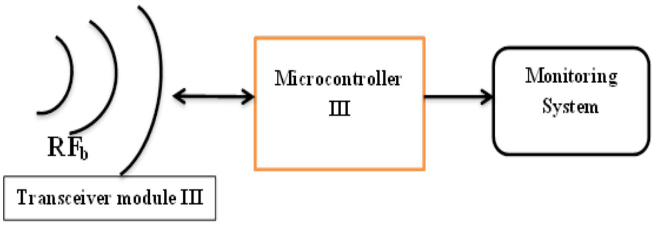

Fig. 4 Monitoring Controlled System

C. System Methodology

The performance of the proposed system is based on basic principles and formulas. The basic principles of the state condition of a user in the office area are divided into active and non-active. The probability when one condition changes to another or when conditions remain the same is presented. Fig. 5 shows that every condition that probably occurs in the office area and the transition state when one condition changes to another.

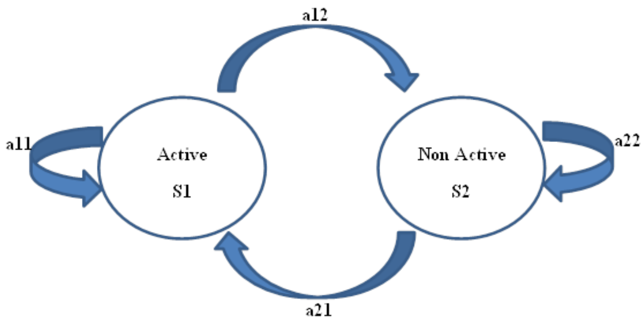

Fig. 5 Transition state of every condition in an office

When the state of activity inside the office changed from one state to another, the system will show the result according to the conditions. If movement is detected, the status of movement will become 1 or remain 0 otherwise. However, every state will change according to the status detected within a different time range. When the sensor is triggered and C = 1, the system will start to activate. The state would remain unchanged if any movement is detected every 5 min. The state would start changing from active to non-active if no movement is detected within 10 min. When the sensor is triggered and C = 0, the system will start to activate. The state would remain unchanged if no movement is detected every 5 min. The state would start changing from non-active to active if movement is detected within 5 sec. The operations will run continuously for 24 h. The switches of relay, which control the electrical appliances, will remain ON during active state and will remain OFF during away state. Table I illustrates the condition for every transition state according to sensor feedback.

Table I Transition table of every condition in office

	Time Taken (t)	**Movement (M)/ Sensor (C)**	**Current State**	**Next Estimated State**	**Switch State**
a11	5 min	1	Active	Active	ON
a12	10 min	0	Active	Away	OFF
a21	5 sec	1	Away	Active	ON
a22	5 min	0	Away	Away	OFF

According to the electrical appliances used in daily life, a wattage list is available for every appliance. Moreover, a basic formula is provided to calculate how much energy is spent per day, month, or year. The related formula is:

Equation 1 Energy Used of Electrical Appliances

$$\frac{Watts\ *\ Hours\ used\ per\ day * Days\ used\ per\ year}{1000} = Kilowatt - hour(kWh)\ Consumption$$

IV. RESULTS AND FINDINGS

The working area consists of several offices in each row. Each office has a light bulb, air-conditioner, and desktop

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computer. The specific office in the middle is setup as the monitoring system room to receive data easily from all the offices in same floor. The working area is considered to evaluate the proposed SESMS for collecting data on how many hours of power are used in a day, a week, a month, and even a year. The map of the working area is presented in Fig. 6. The average power usage of electrical appliances in the office is shown in Table II.

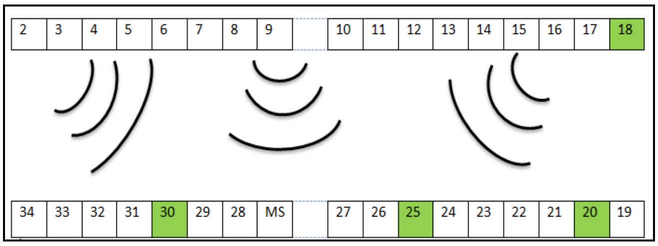

Fig. 6 Map of Working Area

Table II Power Average Usage for the Electrical Appliances

Appliance	**Power(Watts)**
Room air-conditioner	5200
Laptop computer	40-120
Desktop computer	80-120
Fluorescent light tube	36

The interface of the Monitoring Control System was designed to collect data easily and to show the information clearly to the users. The results are shown in the design presented in Fig. 7. In Fig. 7, the interface of the monitoring system indicates the status of every office according to the data collected. The system includes the graph of the collected data daily (see Fig. 8). In Fig. 8, the x-axis represents the watts of electrical appliances used in a day, whereas the y-axis represents the room number of the offices. The collected data will display clearly and automatically in Microsoft Excel and will show the design presented in Fig. 9. Fig. 10 shows the data analysis of power consumption of the area.

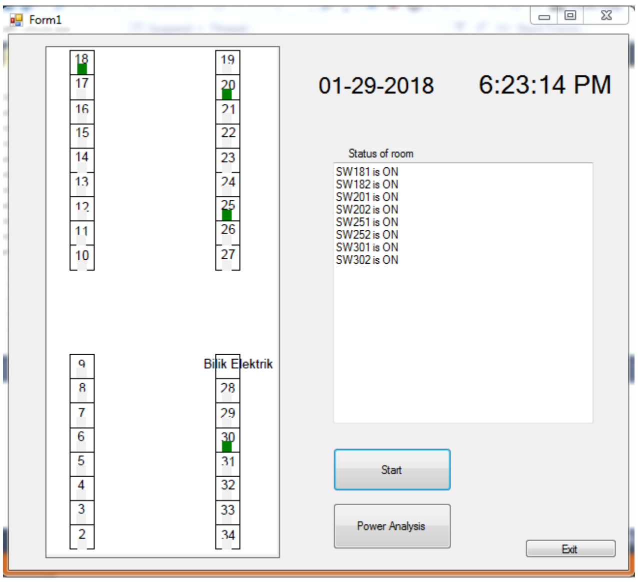

Fig. 7 Interface of Monitoring Controlled System

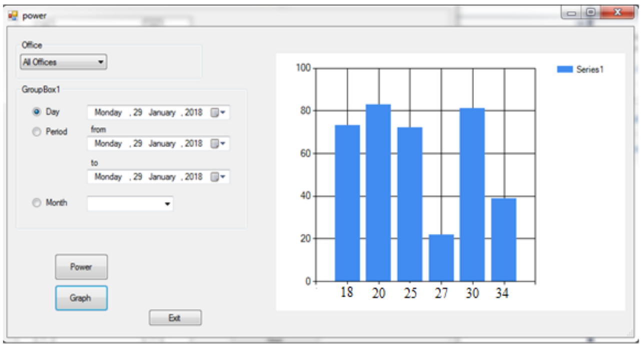

Fig. 8 Graph of power assumption in daily

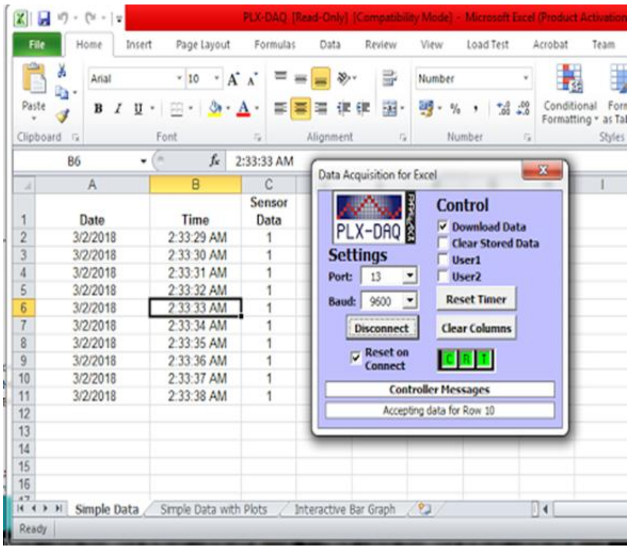

Fig. 9 Data Collected

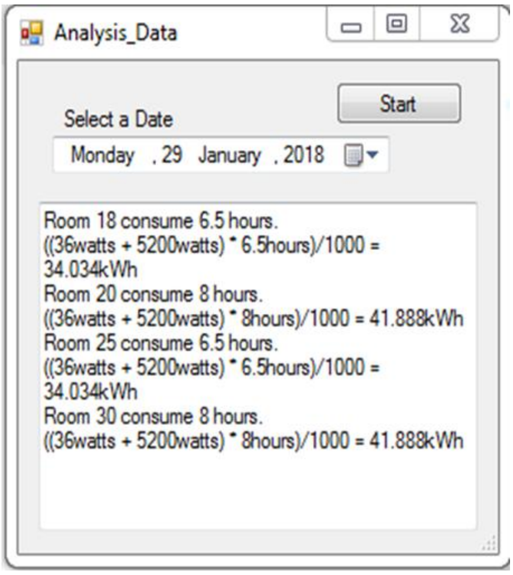

Fig. 10 Analysis Data

Table III Power save by different people in different task

Staff/ Student	**Working Hours (h)**	**Power Save (kW)**	**Power Save in Percentages (%)**
Lecturer	8	9.7739	23.00%
Post-doc	8	12.1301	27.04%
Lab assistant	6	10.2975	30.73%
Admin	8	10.2975	24.23%

Student in lab	6	0.2618	0.78%
Student in workstation	8	4.1015	9.31%

The result of total power saved by different people with different task in certain area is shown in Table III. In Table III, there are students and staff was been found under an experimental work at different working places. The power used was calculated based on their standard working hours. From the analyses data, the system able to estimate the percentages of power save.

In Fig. 11, the result was been analyzed based on the data in system. The system able to save more power for a staff compare to student in a working places. The working places for staff is more suitable to place the system than a student as we know that the staff office is personal belonging whereas the lab or workstation is shared with numerous of students. From the figure the office of lab assistant could be save the power the most among other staff as normally they active in lab, workstation, lecturer hall or other places in working hour. The working hour for a post-doc staff is uncertainly and probably they need outstation sometimes. So the system is needed help to save the power in the office of post-doc staff all the time. Besides that, the system is needed to place in office of lecturer too because lecturer sometimes need teaching in the lecturer hall or carry out the research in lab or workstation. With the aid of the system it might help to switch off the electrical appliances in the offices when the lecturer is not around. For the admins offices, the staff away from the offices when lunch time or attend for a meeting and the system will help to control the operation of electrical appliances in the offices. Some of the working places like lab or workstation are not preferable to apply the system since the machine or computer in that places are operating all the time in working hour.

In Fig. 12, the result showed the overall percentages of total power saved for the system. In the workplace of lecturer, the system able to save up to 23%, for the workplace of post-doc staff the system save 27.04%, for the workplace of lab assistant the system save 30.73% which is the most the power save among others, for the workplace of admin the system save 24.23%, for the workplaces of student in lab and workstation the system save only 0.78% and 9.31% respectively. From the result showed, the system is more reliable to place in offices compare to the workplace and also higher demand for a staff compare to student.

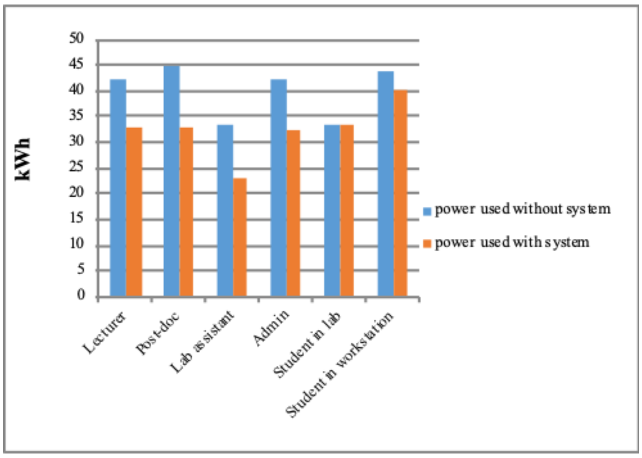

Fig. 11 The differences of power before and after the system is used

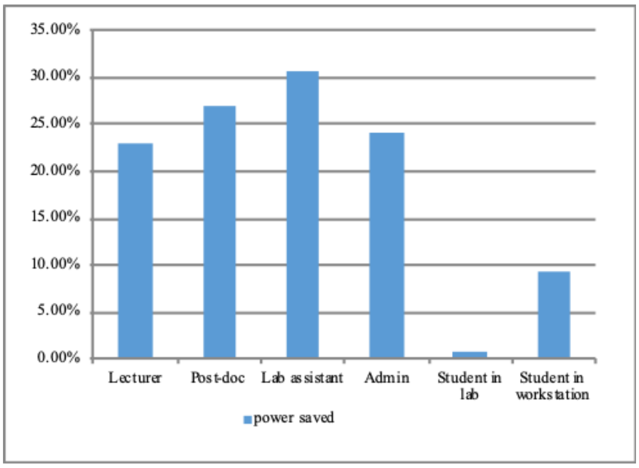

Fig. 12 Percentages of total power saved

V. CONCLUSION

Smart technology system plays an important role in saving energy without adding any necessary courses to learn to manage energy usage or acquire any expensive equipment to reduce power usage. The proposed SESMS increases the convenience and saves power for users. Moreover, SESMS provides a reliable system designed for use in the working area to control electrical appliances more systematically and measure power consumption daily. This system is useful and convenient especially for the workers who are busy with their office jobs. In the future, this fully automated system could be improved and become more flexible to control automatically and annually. Different types of sensors could be added to increase the accuracy and precision of the system.

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