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Application of an Energy Management System via the Internet of Things on a University Campus

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ABSTRACT
This study developed an energy management system (EMS) via internet-of-things (IOT) for lighting control on a university campus in Taiwan. The system structure of EMS was composed of five layers: a network layer using WebAccess, an application layer using software and controllers, a control layer using remote I/O, an equipment layer using the lighting equipment, and a perception layer using light sensors. The proposed system for lighting control on a university campus was completed successfully and running smoothly online. This study provides valuable reference in engineering and technology education employed in training and development programs.

Keywords: energy management system, internet of things, IOT, sensor

INTRODUCTION

As the energy used in buildings keeps increasing, energy conservation issues are getting more attention globally (Cheng et al., 2015). Energy efficiency is a critical issue for campus buildings as it is associated with students' comfort and indoor air quality (Tsai et al., 2010). Building an energy management system (EMS) is meant to promote a new generation of energy management for reducing buildings' energy usage, associated costs and carbon emissions. EMS is a combination of building management systems and advanced software solutions that assist in managing building functions in a more energy efficient way. Energy management is utilized for saving energy by managing the energy usage of sites or facilities through the application of microprocessor, computer, ethernet, internet, and wireless sensor network.

There was a case involving the requirement to improve the energy management system on campus, as an emerging area of institutional research, by the use of engineering techniques to increase member awareness and involvement for smart energy management (Kusakabe et al., 2014).

Energy use can be controlled in order to reduce costs and maximize profits. The controls can be as simple as manually turning off a switch; however, automated controls ranging from simple clocks to sophisticated computers are often required. An effective energy management system is one in which the controls are as simple and reliable as possible while still meeting the basic safety needs of the equipment and the operators. Unneeded equipment is turned off, and needed equipment and systems are operated in a manner that reduces energy costs. An appropriate control system may include reductions in the electric power used, energy requirements of the equipment, as well as the power and energy requirements associated with other forms of energy.

A university is usually made up of an eclectic mix of buildings, including research facilities, libraries, offices, auditoriums, dormitories, classrooms, dining halls, and in this case a central steam-heating plant, individual building chillers for air conditioning, thousands of lighting fixtures and exit lights. Therefore energy management is a major concern on university campuses.

Internet-of-things technology has changed the educational landscape by allowing educators and administrators to turn data into actionable insights. Verma et al. (2017) showed that by introducing IOT in engineering education,

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Contribution of this paper to the literature

- This study presented energy management system application based on IOT technology for lighting control for university campus.
- First, the proposed system allows the user to better understand the energy consumption of each single appliance, thus bringing him/her to make more intelligent choices in terms of energy consumptions.
- Secondly, the proposed system allows improved energy efficiency by means of an appropriate management of each single appliance, depending on rules specified by the user.
- Finally, the experimental results provided significant energy savings, by eliminating standby consumptions and/or adapting the behavior of appliances to the real environmental conditions.

more effective decisions can be taken to improve student learning experiences and the over-all growth of the institution. IOT development has been driven by the needs of large corporations that stand to benefit greatly from the foresight and predictability afforded by the ability to track the countless factors involved in production (Baytiyeh, 2014). With the IOT's ability to code and track objects, companies can become more efficient, speed up processes, reduce error, prevent theft, and incorporate complex and flexible organizational systems (Castells, 2001). Environmental protection and green education are important global issues. The IOT is a new effective communication medium for advertisement and information dissemination to promote a variety of concepts (Tu et al., 2017).

The IOT signifies a technological revolution that represents the future of computing and communications its development depends on dynamic technical innovation in a number of important fields. Connectivity between IOT smart objects is achieved under advanced communication standards (Atzori et al., 2010; Souza & Amazonas, 2015) typically composed of sensors and radio frequency identification (RFID) systems.

The rest of this study is organized as follows. Section 2 briefly describes the literature review for IOT, WebAccess and an energy management system. The methodology and implementation of our novel IOT energy management system are discussed in Section 3. The results and discussion of the EMS application are presented in Section 4. Conclusions are offered in Section 5.

LITERATURE REVIEW

Internet of Things (IOT) Concepts

Wanyama (2017) provided remote laboratories using industry 4.0 technologies to build industrial networks laboratories that were accessible onsite, and remotely online through the Internet. The IOT is a network that uses the internet to facilitate information exchanges between clients and goods (Lu & Teng, 2012). The IOT accomplishes this through the use of RFID, infrared sensors, global positioning systems, information sensing devices and/or laser scanners. These elements are able to achieve intelligent identification, location, tracking, monitoring, and management.

The IOT is a multi-disciplinary concept. Implementation is only possible through the integration of technologies in the fields of communications, networking, data acquisition, data fusion, cloud computing and security. The enabling technologies can be categorized in terms of their levels of competency (Yang, 2014): (1) technology level - technologies for connecting real or virtual smart objects within the information infrastructure under energy and environmental constraints, i.e. individual wireless sensing capabilities, (2) communication and networking level - technologies for providing massive, efficient, dynamic, flexible and secure communication networking, and (3) intelligence level - technologies for providing data fusion and service discovery where distributed users utilize data collected by individual smart "network enabled" objects.

The IOT can be described from a technical perspective by separating it into three parts (Madakam et al., 2015). The first part is the hardware device layer or the sensing layer. This physical layer occupies less space than traditional hardware, making it easier to connect practically anything, anywhere, and anytime. Wireless sensor networks (WSN) are an outstanding advantage of the IOT at this layer, as it gains information about an object's environment. The second part is the infrastructure or the network layer. This layer consists of a converged network formed by all kinds of communication networks as well as the internet. The IOT management center and information center form the integral parts of the network layer. The network layer allows network operation and improves information operation. Unfortunately, 3G or LTE technology is unable to deal with the millions of devices connected to the internet; 3G is growing, but the current capacity of the mobile networks is acting as a bottleneck. The third part of the IOT is the application layer, which consists of the applications and services that use the vast quantity of information created by the IOT. The application layer can be combined with industry expertise to achieve a broad set of intelligent application solutions. Use of the IOT involves creating new business models and

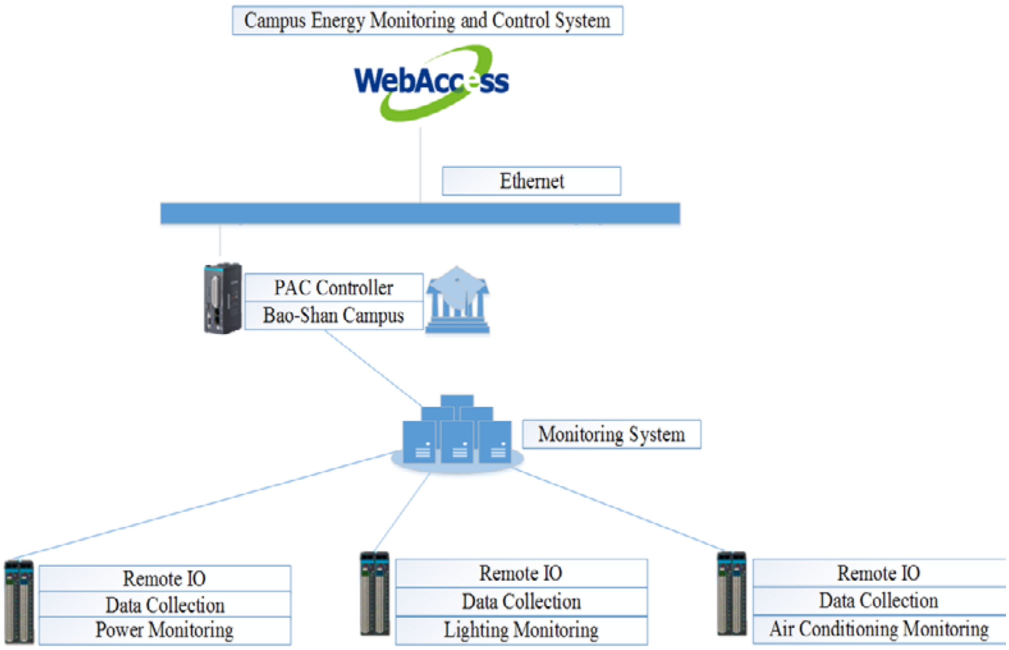

Figure 1. IOT system model1

innovative business initiatives. The main purpose of the IOT application layer is to provide information services it mainly consists of three parts: the IOT client side, data storage modules and data inquiry modules.

The International Telecommunication Union (ITU) suggests that the network architecture of the IOT consists of (1) the sensing layer, (2) the access layer, (3) the network layer, (4) the middleware layer, and (5) the application layers (Own et al., 2013). Shyr et al. (2017) developed the structure of the IOT technique as follows: (1) perception layer, (2) equipment layer, (3) control layer, (4) application layer, and (5) network layer.

IOT Based on WebAccess

The IOT technology based on WebAccess is configuration software that uses Internet Explore to apply TCP/IP protocol. This software uses the open character of the internet to make it a basic part of the Advantech WebAccess system. A client can access the system, make dynamic online editing and master the information of the system using a standard web browser without any restrictions. Advantech WebAccess is one of the best internet control schemes, and the number of clients it can reach is nearly infinite. Advantech WebAccess can also protect the data of users and the whole system.

WebAccess is a powerful piece of graphic monitoring software that is capable of constructing a multifunctional human interface. It can be used for data collection, trend alert processing and reporting systems. The animated operational interface can be configured using mechatronics equipment and controllable I/O devices. This interface provides a number of graphic tools for user convenience. Liu et al. (2008) presented an automatic control system based on WebAccess software for intelligent buildings offering distributed control and centralized management of buildings. With the powerful ability of WebAccess, various subsystems can be integrated effectively.

This study proposes IOT technology with the use of the WebAccess system for energy management. The proposed system includes a perception layer, an equipment layer, a control layer, an application layer and a network layer. Figure 1 shows the model for the proposed IOT system, with the functions described below.

(1) *Perception layer*: The perception layer is the first layer shown in Figure 1. All the data collected from the outside world was done in this layer with the use of a light sensor.

(2) Equipment layer: The equipment layer is the second layer. The data from the light sensor was collected in digital form and sent further for the next procedure.

(3) Control layer: The control layer is the third layer. The data for remote I/O controller proceeded in this layer.

(4) Application layer: The application layer creates the IOT and makes interfaces and achieves the intelligent application of IOT. All the applications converge in this layer. Software developers should make the software and applications user friendly with the knowledge of the application layer.

(5) Network layer: The use of the internet layer is to set up the internet connection and save the logs of the connections. The central monitoring system of the data is upheld in this layer.

Energy Management System (EMS)

Energy management includes all the measures that are planned and implemented to ensure minimum energy consumption for the current activity. The energy management influences organizational and technical procedures, as well as behavior patterns, in order to reduce the total operational energy consumption, to use basic and additional materials economically and to continuously improve the energy efficiency in the company. An EMS systematically records the energy flux, and serves as a basis mainly for investments in improving energy efficiency. A functioning EMS helps a university to comply with the commitments made in its energy policy and to continuously and systematically improve its energy performance. EMS encompasses all the elements of an organization that are necessary for creating an energy policy, and defining and achieving strategic objectives. It thus includes the organizational and informational structures required for implementing energy management, including resources. It formulates and implements the energy policy, with the planning, introduction and operation, monitoring and measurement, control and correction, internal audits, as well as a regular management review.

METHODOLOGY AND IMPLEMENTATION

The IOT is a new and effective integrated technology based on the internet, including hardware, software and firmware. The applications of IOT will be promoted all over the world without time and space constraints. The IOT can let the automated machines interactively communicate with consumers and raise consumer involvement to strengthen consumers' impressions and increase consumers' purchasing power (Smith, 2012).

The integration of sensing systems with internet monitoring is likely to optimize energy consumption in general. IOT is likely to be integrated into lighting devices to allow them to communicate with the utility supply company in order to effectively balance power generation and energy usage. Such a system would also offer the opportunity for users to remotely control their devices, or centrally manage them via a cloud-based interface, and enable advanced functions like scheduling (e.g., remotely turning heating systems on or off, controlling ovens, and changing lighting conditions).

Okafor et al. (2015) proposed a robust smart green energy management system with an integrated energy monitoring and management platform that works as a cloud computing datacenter. Marvin et al. (2013) promoted a smart home electricity management system using cloud computing. The Internet can collect on-line data power consumption and manipulate the power supply of the connected electrical appliances. It can generate daily, monthly and yearly reports on cost and usage of each appliance/load connected to the system. Thus, it enables the consumer or establishment to keep track of the real-time power consumption which allows users to save electrical energy. Bhagyashree et al. (2014) proposed a technology that can perform remote control and monitoring of electrical appliances on the internet. An intelligent power socket (IPS) module that is able to control and monitor the power of electricity was realized.

Smart buildings can be considered green buildings with better performance enabled by information and communication technology (ICT), the IOT and other advanced technologies (Strife, 2010). Smart buildings integrate a wide variety of fields such as architecture, energy management, safety monitoring, energy-saving household appliances, automatic control, air-conditioning energy conservation, indoor environment quality, water conservation, and lighting management. Therefore, in addition to equipping students with architectural knowledge, it is important for a traditional university education in architecture to cover the emerging technologies used in smart buildings as well (Rogado et al., 2015).

Lighting controls are an excellent way to reduce energy expenditure while enhancing lighting quality. Occupancy sensors can eliminate wasted lighting in unoccupied spaces. Day lighting controls or advanced load management can reduce lighting demand at the times when energy is the most expensive. Manual dimmers, which allow occupants to adjust light levels to their preference, are becoming more affordable. Lighting controls have been shown to reduce lighting energy consumption by 50% in existing buildings and by at least 35% in new construction (Kibert, 2016). Digital lighting control systems have been developed as stand-alone systems or as a part of building-wide automation systems. In a digital system, each segment of the lighting system has its own device-specific address/location. This allows commands to be issued to specific portions of the building's lighting system. Digital systems can perform the same lighting automated functions as independent, stand-alone systems, only perform them better. It can schedule the operation of lights in any area within the facility, and it can override the set schedule to match changes in operating schedules. It can monitor occupancy patterns in an area and adjust the operation of the lighting systems as required. Digital systems also give facility executives the ability to control building lighting energy use from any location. In addition to providing a central control station for the building's lighting systems, most digital systems are internet-compatible, allowing managers to monitor and control building lighting systems from any location that has an internet access. The ability to remotely control building lighting systems is particularly important for facilities facing high or uncertain electricity costs. One method of reducing

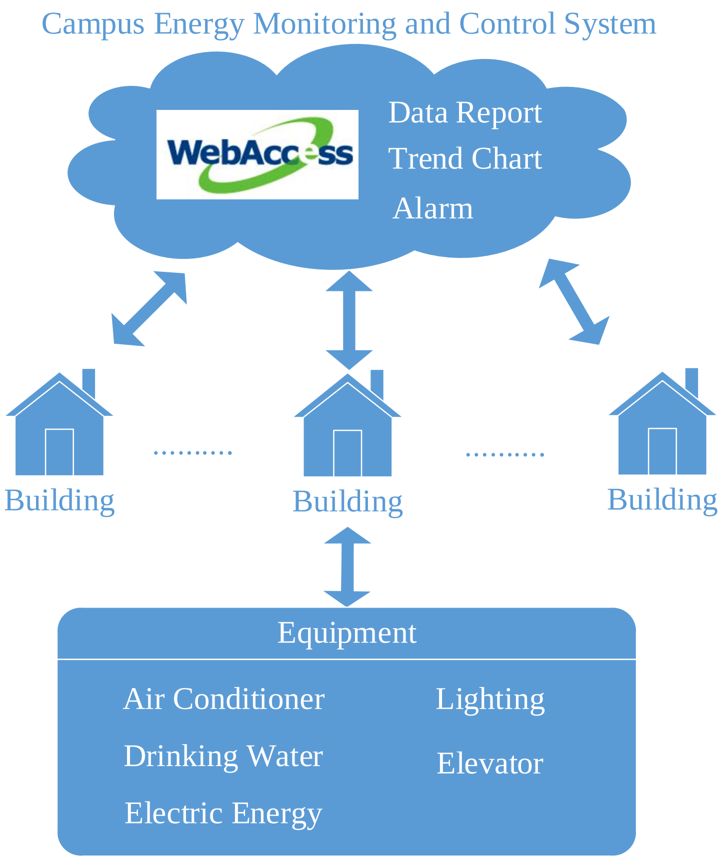

Figure 2. Energy management system

those costs is to limit the facility's demand for electricity during peak-use periods when the rates are the highest. During these times, the lighting control system can turn off as many components as possible, or dim those systems that are equipped with dimming ballasts. With lighting systems accounting for such a large portion of the electrical load, any reduction in lighting load during peak-rate periods will translate into savings, in both energy use and energy demand charges.

Another benefit of digital lighting control systems is their ability to monitor the operation of the lighting systems. At the minimum, the digital system can receive feedback from each component, confirming that it is on or off as commanded. The digital system can also monitor the number of hours that the lights operate in a given area, as well as the number of times the lights are turned on, which are the most important factors in determining lamp life. Using this information, managers can schedule the relamping of particular areas in the building before the number of lamp burnouts becomes excessive while also ensuring that the lamps have been used for as long as possible (Pan et al., 2011). Lighting controls reduce building operation costs. Since every building is different, it is difficult to know how much energy lighting controls are likely to save in any given application. The energy savings from controls depends on how the building lighting operated before the controls were installed. If building occupants were conscientious with lighting, then energy savings will be modest. However, automatic controls can significantly reduce wasted lighting energy in many buildings by eliminating lighting during unoccupied times or reducing electric light levels where adequate daylight is available (Wu et al., 2016).

RESULTS AND DISCUSSION

This study is a case study of a lighting management system using IOT technology. The system was developed for a university campus in Taiwan. The system structure was composed of five layers: a network layer using WebAccess, an application layer using software and controllers, a control layer using remote I/O, an equipment layer using the lighting equipment, and a perception layer using light sensors.

Figure 2 is the snapshot of the web page for the energy management system, which provides a status overview of each wireless gateway of individual households on a university campus. **Figures 3-4** respectively show the case study of lighting control panel which depends on the floor schedule table and the occupancy pattern.

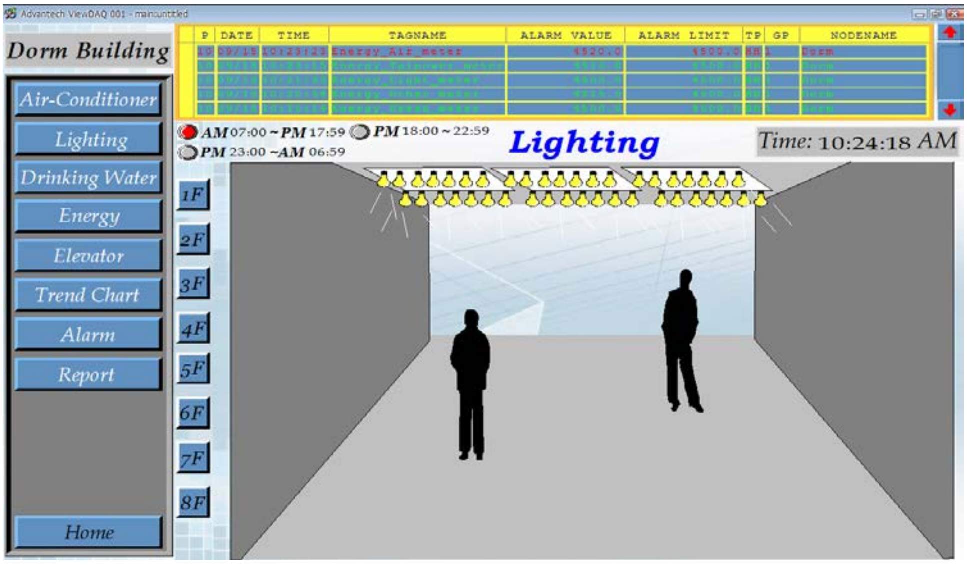

Figure 3. Lighting control panel

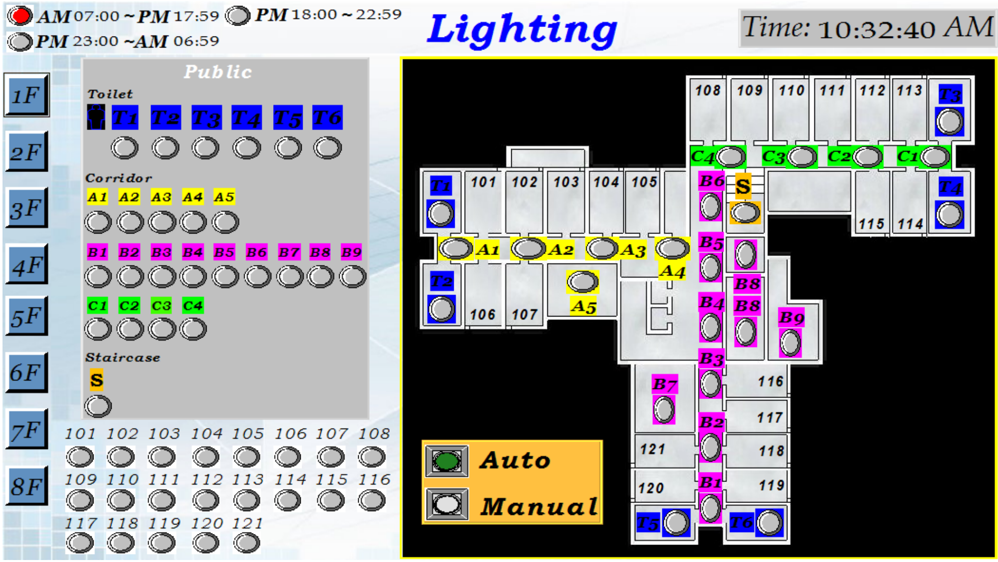

Figure 4. Floor schedule table and occupancy patterns

The proposed EMS supports the following functions: (1) The lighting control panel remotely monitors the illumination in any room. (2) The daily load curves display the load curve for any chosen room and calculate the total energy consumption. (3) Energy management features make the energy conservation calculations, allowing users to print the specific outcome in tables, as well as a list of final results that indicate all forms of energy saving.

This EMS achieves its objectives through several functions. The main function is to turn the lights on and off depending on the schedule for the lighting area and occupancy patterns. The schedule was downloaded from the university server at the beginning of each semester. The lights turn on in a classroom when two conditions are met: there is a lecture scheduled for that time, and the occupancy sensor detects motion (when the students enter the room for example). Otherwise the lights remain off. Through this system, the university was able to achieve maximum possible savings.

Another feature that this system provides is for special events. This option allows instructors to override the programming mentioned above if they want to lecture on a different schedule. They are able to enter the room number, the start time, the end time, and the date of the desired lecture. When they submit this information, the system checks that the times do not conflict with the existing schedule. The control panel also allows a user to monitor the university facilities by displaying all the floor schedules and their occupancy patterns, or searching for a specific room number to show whether lights are on or off. The system accounts have three levels of permissions for the users: administrator, instructor, and security. The administrator has full access to modify the system. The instructors can monitor and assign new lecture times, and limited permission is given to security.

CONCLUSIONS

This study presented energy management system applications based on IOT technology for lighting control for a university campus. The goal of the proposed system is twofold. On one hand, it allows the user to better understand the energy consumption of each single appliance, thus bringing him/her to make more intelligent choices in terms of energy consumption. On the other hand, it allows improved energy efficiency by means of appropriate management of each single appliance, depending on the rules specified by the user. The experimental results provided significant energy savings by eliminating standby consumptions and/or adapting the behavior of appliances to the real environmental conditions. Actually, current costs of electricity sensors and actuators are very high. However, they are expected to decrease as soon as their penetration in the market increases. In addition, next-generation electrical appliances will include built-in sensors and actuators.

The proposed system for lighting control on a university campus was completed successfully and runs smoothly online. With further research, other energy management will be used in intelligent buildings. In the future, the electricity usage information can be further analyzed for equipment diagnosis and demand predictions, and contribute more benefits to the campus energy conservation.

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