Electrical Power Consumption Monitoring in hotels using the n-Core Platform

Óscar García
Ricardo S. Alonso
Dante I. Tapia
Nebusens, S.L. R&D Department
Salamanca, Spain
{oscar.garcia, ricardo.alonso, dante.tapia}@nebusens.com

Juan M. Corchado
BISITE Research Group
Department of Computer Science and Automation
University of Salamanca
Salamanca, Spain
corchado@usal.es

***Abstract*—One of the problems that affects the management of large buildings is energy consumption. Wireless sensor networks are presented here as a great ally for the optimization of energy consumption. Thanks to the integration of temperature, lighting, humidity, air quality or gas sensors, combined with different actuators that can monitor and regulate the level of work of energy-consuming devices, and software management and analysis, energy consumption in large buildings is significantly reduced without decreasing the availability and effectiveness of resources. Hotels are a kind of ideal building to implement these systems. Nebusens has launched a pilot in a hotel, so energy consumption points can be monitored (HVAC, boilers, etc.), thanks to the implementation of the sensors that are integrated into its platform n-Core using its management software Polaris. Thus, the energy consumption has been reduced by up to 35% since the introduction of the pilot without any decrease in quality of service.**

***Index Terms*— Building Energy and Comfort Management, Energy Monitoring, Energy Saving, Wireless Sensor Networks.**

I. Introduction

Energy consumption is one of the problems in which more efforts are being carried out. The efficient use of energy helps the sustainability of the planet and allows saving natural resources and reducing pollution.

Monitoring energy consumption is considered as a fundamental tool in optimizing the use of energy resources. In this sense, technology becomes a key tool to collect real-time information and present statistics from the energy consumed by any device.

Large buildings are places where the application of technologies for monitoring energy consumption will be more efficient due to the high energy costs associated with. The many points of light, both deployed in private and public areas, air conditioning and heating boilers, extraction systems, elevators or laundry rooms, are critical points where energy leaks appear and their optimization reduces significantly the global energy consumption. With these data, hotels can be considered a type of building where energy consumption is a major challenge.

This paper presents the implementation of a Wireless Sensors Network (WSN) system in a large Mexican hotel. Different energy consumption points can be monitored (HVAC, boilers, light panels, etc.), thanks to the implementation of the sensors that are integrated into the platform n-Core using its management software Polaris. The information gathered by the sensors is presented in real time to the hotel management. Thus they can detect vanishing points of energy that are fixed, places where inefficient use of it is taking place or even reduce energy consumption by monitoring parameters such as brightness from sunlight or ventilation.

Thanks to the implementation of Wireless Sensor Networks and the management and analysis software tools, energy consumption in the hotel has decreased significantly thanks to the optimization of natural resources, choice of light sources with more economic consumption or temperature management in common areas or large halls.

The rest of the paper is structured as follows. Section II details the problem background including the choice of technology. Then, Section III describes the environment and the system that is implemented. Section IV presents the actions that have been carried out thanks to the monitoring of energy consumption as well as some of the savings that have been achieved thanks to its application. Finally, Section V presents the conclusions obtained and the future work.

II. Problem Background

Electricity is one of the most important sources of energy which has a great impact on human life and in its economy [5]. Within the overall energy consumption, buildings consume between 30% and 40% of it [6], so it is considered a sector in which the implementation of energy saving measures can have more impact [7]. Thus, reduce energy consumption is vital for several reasons: on one hand because of the environmental impact preserving finite resources. On the other hand, cost reductions are significant for both private individuals and companies [5].

The acronym BECM (*Building Energy and Comfort Management*) defines control systems for individual or groups of buildings in which technology is used for monitoring, data storage and communication [8]. Intuitively it can be determined that HVAC (Heating, Ventilation, and Air Conditioning) systems, lighting and electricity control are parts of the building energy system to be supervised by the BECM systems, which main goal is to reduce energy consumption during building operations keeping all functionalities required by users [9].

Wireless Sensor Networks (WSN) are widely recognized as one of the technologies to deploy BECM, providing a low-cost solution for energy metering and control management [12]. The potential of WSN includes advance metering, demand response, fault detection, remote system monitoring and the implementation of sensors to detect luminosity, temperature, presence, or air quality among others [11]. For example, different researches conclude that using real-time occupancy information helps to save electrical energy used for lighting [10].

Wireless Sensor Networks are used for gathering the information needed by monitoring systems in different sectors such as Smart Cities or home and building automation, industrial applications or smart hospitals [1, 2]. Wireless Sensor Networks support current requirements for BECM related to the deployment of networks that cover communication and data collection needs, providing flexibly in time and space as they do not require a fixed structure [3, 4]. Several wireless technologies, such as ZigBee, Wi-Fi or Bluetooth, enable easier deployments than wired sensor networks. With wireless technologies users avoid the need to wire buildings, decreasing the costs of the setup phase.

The range of applications that can be developed using WSNs is wide: the goal of this paper includes energy monitoring and management and environmental data gathering. Moreover, the same infrastructure allows user to deploy other systems that add value, such as security and access control in buildings, as well as industrial and home automation, among many others. Building automation and control systems started with wired technology but currently wireless technologies, such as ZigBee, provide a full range of functionalities that allows these systems to be deployed quickly and efficiently, reaching up to 80% energy saving in these systems [13].

The system that this paper presents has been developed using the n-Core Platform [14], which is briefly described in the next subsection.

A. The n-Core Platform

Nebusens and BISITE Research Group has developed the n-Core platform. This platform is based on the IEEE 802.15.4/ZigBee international standard and operates in the 868/915MHz and 2.4GHz unlicensed bands. ZigBee standard is designed to work with low-power nodes and allows up to 65,534 nodes to be connected in any kind of topology network, such as star, tree or mesh [15]. n-Core platform consists of several modules, fully integrated among them, which provide all the functionalities to deploy WSNs and to develop any software application needed.

On one hand, the platform provides a set of radio-frequency devices, called n-Core Sirius. Each n-Core Sirius device includes an 8-bit RISC (Atmel ATmega 128RFA1) microcontroller with 16KB RAM, 4KB EEPROM and 128KB Flash memory and an IEEE 802.15.4/ZigBee 2.4GHz (AT86RF231) transceiver, as well as several communication ports (I2C, ADC, JTAG, SPI, GPIO and UART) to connect to almost every kind of computer, sensor and actuator [14].

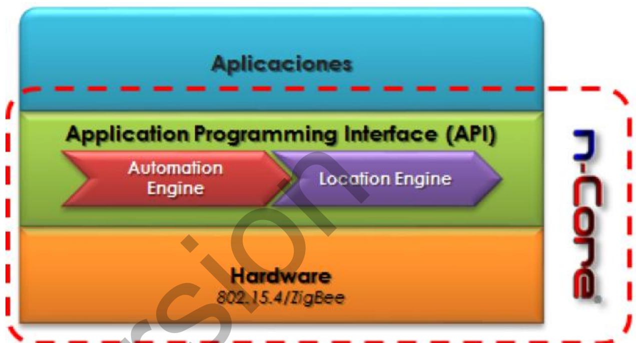

Figure 1. Main components of the n-Core Platform.

On the other hand, all n-Core Sirius devices are programmed with a specific firmware that offers all its functionalities, facilitating the work of developers as they do not have to develop any embedded code. Thus, developers or integrators can simply configure the devices functionalities from a specific tool or write high-level code using the n-Core Application Programming Interface (API) from a computer.

Finally, software development is easy through the n-Core API. This layer allows creating easily end-user applications from any compatible language and Integrated Development Environment (IDE), for example, C/C++, .NET, Java, or Python, among many others. n-Core also offers through this API different modules/engines to develop specific applications, including an automation engine that permit controlling any sensor or actuator or a data engine for transmitting general-purpose data frames among hardware devices. Moreover, the platform also offers a location engine that includes algorithms to calculate the position of any n-Core device into the network deployed.

Therefore, the functionalities provided by the n-Core Platform allow building systems in a wide range of application areas, including home automation (control of lighting and HVAC, control of electronic devices, security), environment (monitoring of environmental data, irrigation systems, animal tracking) or energy (control of energy costs, monitoring of consumption patterns), among others.

Among the wide variety of existing buildings, hotels are presented as an interesting case of use reduce their energy consumption through the implementation of WSNs. Reducing of electrical energy consumption of the large number of points of light, and the diversity of public and private spaces (halls, laundry, corridors, kitchens, rooms, etc.) in which both lighting and HVAC points are key part in the proper functioning of the hotel, presents a big challenge ahead.

Throughout the following sections, the paper describes the WSN that has been deployed in a hotel in Mexico. The goal is to monitor electricity consumption and make the necessary changes in the network to reduce this consumption without reducing the quality of service.

III. SYSTEM DESCRIPTION

The case of use presented in this paper is based on the implementation of WSN throughout the infrastructure of a hotel. It is intended to control the electrical consumption of the rooms, the hallways, the elevator halls, the stairs and the conference rooms.

A. *Hotel distribution*

The hotel in which the system has been deployed is formed by eight floors, a basement and a ground floor. The distribution of each floor is as follows:

- Basement:
  - Two elevator halls.
  - One stairs.
- Ground floor:
  - Three elevator halls.
  - Four stairs.
- First floor:
  - Three elevator halls.
  - Seven corridors.
  - Five stairs.
  - Two Lounges type A.
  - Two Lounges type B.
- Second floor:
  - 33 rooms.
  - Three elevator halls.
  - Ten corridors.
  - Three stairs.
- From third to eight floor:
  - 38 rooms.
  - Two elevator halls.
  - Twelve corridors.
  - Three stairs.

In order to better understand this distribution, a brief description of each area is described below:

- *Elevator halls* are the spaces in front of each elevator. All of them are provided with two light walls that are working 24 hours a day.
- *Stairs* define different areas that connect two floors which are formed by two sections and three flat areas. Each area of this type includes 4 wall lights that are working 24 hours a day.
- Halls have been divided into different sections called *Corridors*. Each section is illuminated by five halogen lights that are working 24 hours a day.
- *Lounges type A* are public use areas in which meetings, conferences or other events bringing many people are held. Both of them are currently provided with multiple points of light and two separate HVAC systems that work under demand.
- *Lounges type B* are smaller public use areas used for meetings. Both of them are currently provided with multiple points of light and one HVAC systems that work under demand.
- Each *Room* includes four halogen lights, two lamps and two wall lights.

With this arrangement, the management of the hotel has the following objectives to be achieved with the use of wireless sensors network. The first objective is to identify electrical power consumptions in each elevator hall, each corridor and each stair. These areas are quite important as they are working 24 hours a day. Secondly, the energy consumption of the rooms will be analyzed each floor, including the consumption of all the rooms. Thirdly, in the lounges, lights and HVAC electrical power consumption will be analyzed separately. Lights in Lounges type A are separated in four blocks that are analyzed separately. In Lounges type B lights are separated in two blocks that are analyzed individually. The power consumption of each HVAC system in these areas will be analyzed separately.

B. *Wireless Sensors Network description*

As discussed above the WSN designed for the monitoring system uses the n-Core platform. The platform includes various hardware devices interconnected that collect environmental data and electricity consumption of each electrical panel of the areas defined above.

The WSN architecture is very simple: each monitoring point, both for collecting energy consumption or environmental data, is connected to a device of the Sirius range that the n-Core platform offers. The Sirius devices send the information in real time through the ZigBee network formed by themselves to a server where it is stored in a MySQL database. This information is provided to users through the monitoring and location software POLARIS. This software has been developed using Web Services, so that anyone with permission can access the information through a web browser running on a smartphone, tablet or computer with Internet connection.

In this phase of the project monitoring and sensing points used are as follows. The power consumption of different panels of lights that are used in the corridors, elevator halls, rooms, stairs and lounges is measured by an electricity meter connected to a Sirius A device that transmits the consumption data in real time to the server where all the information is stored.

In the different areas where lighting is working 24 hours a day (stairs, corridors and elevator halls) it has been installed a presence sensor and a light sensor, both connected to a Sirius RadIOn device that transmits the information of each of them to the server. These sensors have two primary objectives in the system: firstly, they will detect if there is the presence of someone in the areas described; only if the presence is positive the corresponding light will be activated. Thus the illumination is not working 24 hours a day. On the other hand, the light sensor will be responsible for detecting whether sunlight is sufficient to illuminate the area when the presence of people is positive. If this occurs, the lights will not be activated even though there is the presence of people.

Regarding the control of HVAC systems, a meter is connected to a Sirius A device to determine their electrical consumption on real time. Moreover, temperature sensors, connected to Sirius RadIOn devices, are deployed through the lounges. Thus, temperature will be determined in different areas and the use of HVAC systems will be optimized. This make sense when many people is using the lounges: those areas where the concentration of people is higher suffer an increase of temperature and, just as happens in the opposite direction, the areas in which there is not a large number of people will benefit from a lower temperature. In both cases, the system regulates the temperature, to get it optimal efficiently.

IV. RESULTS

Throughout this section the results obtained after the deployment of WSN are presented. Firstly, the different consumptions, previously to the deployment of the system, for each area are presented. Then consumption after the deployment and implementation of the WSN system is detailed. After this, results are depicted and analyzed. Note that in this phase of the project the data that has been collected and analyzed corresponds to the corridors, elevator halls, stairs and rooms.

A. *Previous consumptions*

The light points monitored in this project are three: halogen, wall lights and lamps. The electrical power of each of them is 20W for halogen, 48W for wall lights and 60W for lamps. Table I resumes the light points included in each area described.

TABLE I. LIGHT POINTS MONITORED PER AREA

Lights	Halogen	Wall light	Lamps
Room	4	2	2
Corridor	5	-	-
Elevator hall	-	4	-
Stairs	-	2	-

Table II described the electrical power installed in each area:

TABLE II. ELECTRICAL POWER INSTALLED PER AREA

Power (W)	Halogen	Wall light	Lamps	Total
Room	80	96	120	296
Corridor	100	-	-	100
Elevator hall	-	192	-	192
Stairs	-	96	-	96

With these data, the electrical energy consumption before the installation of the WSN is presented in Table III:

TABLE III. ELECTRICAL ENERGY CONSUMPTION PER AREA BEFORE WSN DEPLOYMENT

Consumption (KWh)	Halogen	Wall light	Lamps	Total
Room	400	480	600	1,480
Corridor	2,400	-	-	2,400
Elevator hall	-	4,608	-	4,608
Stairs	-	2,304	-	2,304

Within these results it should be noted that the number of points of light who work 24 hours a day is very high, increasing significantly the electrical energy consumption. Furthermore, the energy consumption of the rooms is not as high as expected due largely to low average occupancy of the rooms along the day.

B. *Consumptions after WSN system deployment*

Once installed the Wireless Sensors Network, energy consumption varies significantly. These data is shown in Table IV:

TABLE IV. ELECTRICAL ENERGY CONSUMPTION PER AREA AFTER WSN DEPLOYMENT

Consumption (KWh)	Halogen	Wall light	Lamps	Total
Room	400	480	600	1,480
Corridor	1,500	-	-	1,500
Elevator hall	-	1920	-	1,920
Stairs	-	480	-	480

According to the data presented in this section it can be seen that consumption in the rooms has not been modified by the installation of the WSN. However, it can be seen that a reduction in consumption is remarkably in the other areas analyzed.

Thus, the corridors have reduced their consumption by 37.50%, elevator halls by 58.33% and stairs areas by 79.17%. With these results we can draw the following conclusions:

- Presence sensors in stairs areas allow a considerable energy saving. These areas are not frequently used so it is not efficient to keep lighting continuously.
- Elevator halls are favored by sunlight for several hours a day, so this natural resource allows significant energy savings. The combination of presence detector with light sensor allows to perform this upgrade efficiently.
- Energy savings in the corridors areas are not as remarkable as in stairs or elevator hall areas. Still, the use of presence sensors permits to save energy during periods in which the mobility of guests is almost zero, as for example during the nights.

V. CONCLUSIONS AND FUTURE WORK

Saving energy is a strategic point in which diverse entities, such as research centers or governments, are working. The scarcity of natural resources makes that each unit of energy saved is beneficial for the planet and for our future. The importance of this issue makes that many researchers are working effectively in this field.

Buildings are one of the elements where a high consumption of energy is produced. That is why the optimization of energy resources used in them is beneficial both for the energy and cost savings. Among the different types of buildings, hotels have optimal characteristics for implementing energy saving techniques because of its heavy and continued use, that make them being large consumers of electricity.

On the other hand, technology helps to energy savings through the use of devices, techniques and software which allowing monitor and analyze energy consumptions. With the use of technology in control systems for monitoring, data storage and communication appears the Building Energy and Comfort Management. Through these tools for data analysis and decision-making is easier to manage energy systems on a more efficient way.

Wireless Sensors Networks are widely recognized as a technology useful for the design and deployment of home automation and energy metering. Moreover, sensor can collect any environmental data whose information, such as light or temperature, allows a more effective use of energy resources.

The present papers describes the use of WSN in a hotel for electrical energy savings. Several devices and sensors are distributed along the building with the objective of collect and offer real-time electrical consumption information of different areas and data from presence, light and temperature sensors. The use WSN has facilitated savings of up to 79% in areas where it was getting an inefficient use of electricity.

Future work includes next phases of the project, in which electrical energy analysis of other areas will be done and new sensors will be integrated in the network. Moreover, the integration of HVAC systems with the POLARIS software is another issue to be integrated and analyzed.

ACKNOWLEDGMENT

The authors gratefully acknowledge the contributions of Project DREAM-GO: Enabling Demand Response for short and real-time Efficient And Market Based smart Grid Operation - An intelligent and real-time simulation approach, financed by the European Union, program MSCA-RISE-2014: Marie Skłodowska-Curie Research and Innovation Staff Exchange (RISE), number 641794.

REFERENCES

[1] J. M. Corchado, J. Bajo, D.I. Tapia. and A. Abraham, "Using Heterogeneous Wireless Sensor Networks in a Telemonitoring System for Healthcare", IEEE Transactions on Information Technology in Biomedicine. Special Issue: Affective and Pervasive Computing for Healthcare, vol. 14(2), pp. 234-240, 2009.

[2] J. Sarangapani, "Wireless Ad hoc and Sensor Networks: Protocols, Performance, and Control", 1st ed., CRC, 2007

[3] R. S. Alonso, D.I. Tapia, J. Bajo, Ó. García, J. F. de Paz and J. M. Corchado, "Implementing a hardware-embedded reactive agents platform based on a service-oriented architecture over heterogeneous wireless sensor networks", Ad Hoc Networks, vol. 11, pp. 151–166, 2013.

[4] J.M. Corchado, J. Bajo and A. Abraham, "GERAmI: Improving the delivery of health care", IEEE Intelligent Systems. Special Issue on Ambient Intelligent, vol. 23(2), pp. 19 - 25, 2008.

[5] T.A. Nguyen, M. Aiello, "Energy intelligent buildings based on user activity: A survey", Energy and Buildings, vol. 56, pp. 244 – 257, 2013.

[6] United Nations Environment Programme, Buildings and Climate Change Status, Challenges and Opportunities, United Nations Environment Programme, Paris, 2007, ISBN: 9789280727951.

[7] A. Colmenar-Santos, L.N. Terán de Lober, D. Borge-Diez, M. Castro-Gil, "Solutions to reduce energy consumption in the management of large buildings", Energy and Buildings, vol. 56, pp. 66 – 77, 2013.

[8] G.J. Levermore, "Building Energy Management Systems: Applications to Low-Energy HVAC and Natural Ventilation Control", 2nd Edition, E & FN Spon, London, 2000.

[9] WBCSD, Transforming the Market: Energy Efficiency in Buildings, Survey report, The World Business Council for Sustainable Development, April 2009.

[10] A.T.P. So, A.C.W. Wong, K.C. Wong, "A new definition of intelligent buildings for Asia", Intelligent Building Index Manual, 2nd edition, Asian Institute of Intelligent Buildings, Hong Kong, 2011.

[11] E. Fadel, V.C. Gungor, L. Nassef, N. Akkari, M.G. Abbas Maik, S. Almasri, I. F. Akyildiz, "A survey on wireless sensor networks for smart grid", Computer Communications, Available online 11 September 2015.

[12] V.C.Gungor, "Opportunities and Challenges of Wireless Sensor Networks in Smart Grid", IEEE Industrial Electronics, vol. 57, issue 10, pp. 3557 – 3564, 2010.

[13] D.I. Tapia, R.S. Alonso, Ó. Garcia, J.M. Corchado, J. Bajo, "Wireless Sensor Networks, Real-Time Locating Systems and Multi-Agent Systems: The Perfect Team", Information FUSION 2013, pp. 2177 – 2184, 2013.

[14] Nebusens, n-Core®: A faster and easier way to create Wireless Sensor Networks, http://www.nebusens.com/index.php/en/products/n-core. Accessed 19th October 2015.

[15] P. Baronti, P. Pillai, V.W.C. Chook, S. Chessa, A. Gotta, Y.F. Hu, "Wireless sensor networks: a survey on the state of the art and the

802.15.4 and ZigBee standards", Computer Communications, vol. 30, pp. 1655 - 1695, 2007.