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Smart Buildings

Economic impact and user acceptance

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1. Introduction

Besides the technological challenges that a smart building requires, there also exist other ones as human acceptance and economic impact.
When a solution of Smart Building starts to be study, one of the most common question that the manager has in mind is the cost of the investment vs the saving money that solution could bring.
It is not always very easy to estimate those savings, especially for big buildings. Most of the time, the electricity and heating invoices are global for the overall building and they cover a long period of time. It becomes than essential to start by monitoring the current situation to have a good picture on how the heating and lighting systems are used in the building and how much effective a smart solution could be.
Another issue is the user's acceptance. When we decide to make a building "smart" to save energy, for example by a smart light and heat management, we are obliged to use some sensors, and among them, those allowing the detection of the room occupancy. When the room is a big one, knowing if someone is inside or not does not bring any privacy problem. On the other hand, if the sensor is put into an office, knowing if the person is inside or not could be felt by the occupants as an opportunity to supervise their working hours. It becomes than necessary to have an appropriate communication with the staff to let them know the purpose of the smart building and to involve them actively in that process.

The Catholic University of Lille has launch in November 2013 a very ambitious project, called LiveTree (www.livetree.fr), to contribute to the energetic transition of our region Hauts-de-France. One of the aspects of that project is the reduction of energy consumption in the buildings of the University.
This report illustrates a study case of implementation of a prototype to monitor some relevant data in order to identify how the energy in a building is used. Moreover, a study about the acceptance of such a system by the building occupants was also carried out and the results are presented. The study was carried out from September 2016 to April 2017 in the ISA building, an engineering school belonging to Yncréa Hauts-de-France.

2. User acceptance study

First, a communication campaign was launched to explain to the ISA building occupants (students, teachers, researchers, administrators) the goal of the study and involved them in that process of changing the habits to reduce the energy consumption by using new technologies.
A logo was produced and a compelling slogan associated to it **« an ambition, a project … all actors! ».**

The people were informed by mails, flyers and posters about the content of the project, the team working on it, and when the sensors were deployed in the building.

The director of ISA chose to test a solution including temperature, humidity and presence sensors in order to build a heating map, measure the quality of life and encourage the staff to become actor of the energy saving process.
A Google questionnaire was sent to all the ISA employers to know if they heard about the project, and if they wanted to have a sensor in their office. They were also asked about how much useful they find the use of a sensor to reduce the energy consumption.
61% of the ISA staff answered to the questionnaire. 98% declared as being concerned by the the energy saving problems. 91% accepted to have a sensor in their office. Only 11% are not convinced by the added value of a smart building.

Now than the staff is informed about the aim of the project and are ready to see in the building sensors to monitor temperature, humidity and presence, we could deploy the energy-monitoring prototype.

3. Low cost energy monitoring prototype to evaluate the economic impact

We have developed a portable solution to deploy a network of intelligent sensors on any type of building. Indeed, the aim being to be able to increase the number of sensors and the types of sensors, and thus to install this solution in any building at a lower cost. The data collected are stored in the cloud and available for data processing. They can be visualised on a HMI using a tablet.

3.1. Sensor

To do this, we studied different types of sensors, communication protocol and data storage with constraints, quality price ratio and environmental impact.

After considering the different types of sensors available on the market, we decided to focus our implementation of collection services on the Z-Wave protocol especially for cost reasons. As described in the report “Wireless communication for Smart Buildings”, there are a large number of sensors operating on this protocol and coming from various manufacturers (Fibaro, Aeotec ...) and providing useful data for the building's energy instrumentation (temperature, brightness, presence, humidity, etc.).

Z-Wave is a dedicated wireless data transmission protocol for home automation. The theoretical range of the Z-Wave is 40 meters, but this network has the possibility to be extended thanks to the mesh network each sensor of the network can serve as a "relay" to another sensor to the base station processing the data, thus extending the theoretical scope. The company behind Z-Wave, "Sigma Designs", recently made available protocol specifications at http://zwavepublic.com/. The official development kit remains on the other hand paying and the software distribution requires a license and product certification. To incorporate the Z-Wave protocol into our collect infrastructure, we have based ourselves on the OpenZWave available freely project on GitHub: https://github.com/OpenZWave/open-zwave. The project has developed over the years as an alternative to the closed SDK of "Sigma Designs" and is de facto becoming the basis of the majority of open source software for home automation control. It allows access, via interfaces development in C, Python, and Javascript, to the features allowing, the controller start-up and the sensor data recovery.

In order to be able to send the data to the server available in the cloud, the sensors are connected to a RaspberryPi associated with a Sigma-Designs chipset connected to its GPIO ports allowing the transmission of the data to a server using a AMQP protocol. The usual use of the Z-Wave protocol is the domotisation of a classical home. In order to ensure a flexible installation on any building, we have devised a system in which several controllers independently manage a set of sensors and carry all the data to an external server.

3.2. Server management

Our objective is to propose an infrastructure designed as a true platform allowing the development of web interfaces, the management of the sensors network and the data analysis. In order to deploy the necessary applications for the implementation of this infrastructure on the server, we used the Docker containers technology.
Among these applications we have deployed a development platform and APIs for managing the topology of sensors networks, database, data management and analysis and web technology for displaying information.

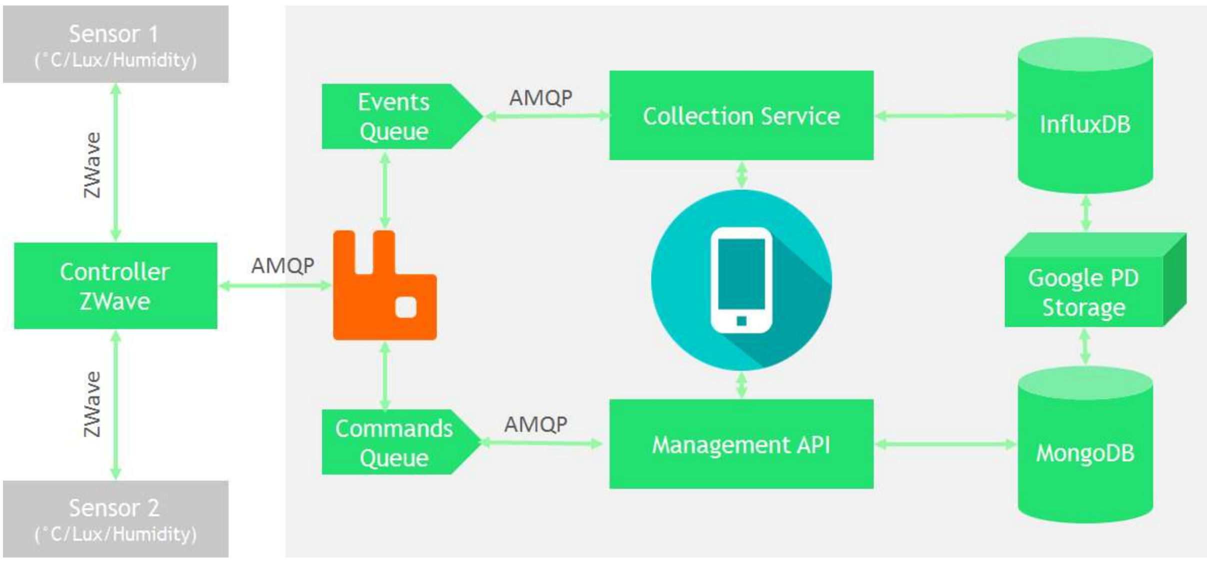

Figure 1: Prototype architecture

A small prototype has been installed at the ISA building. It has 4 sensors assigned in a various locations: classroom, office, corridor and amphitheater. We analyzed 4 parameters: temperature, humidity, luminosity and movement. Each graphic indice was displayed via http://www.smart-isa.fr/dashboard/ website. As mentioned above, if we want to increase the type or number of sensors, this will have no significant impact on our infrastructure.Our solution is portable and suitable for scaling.

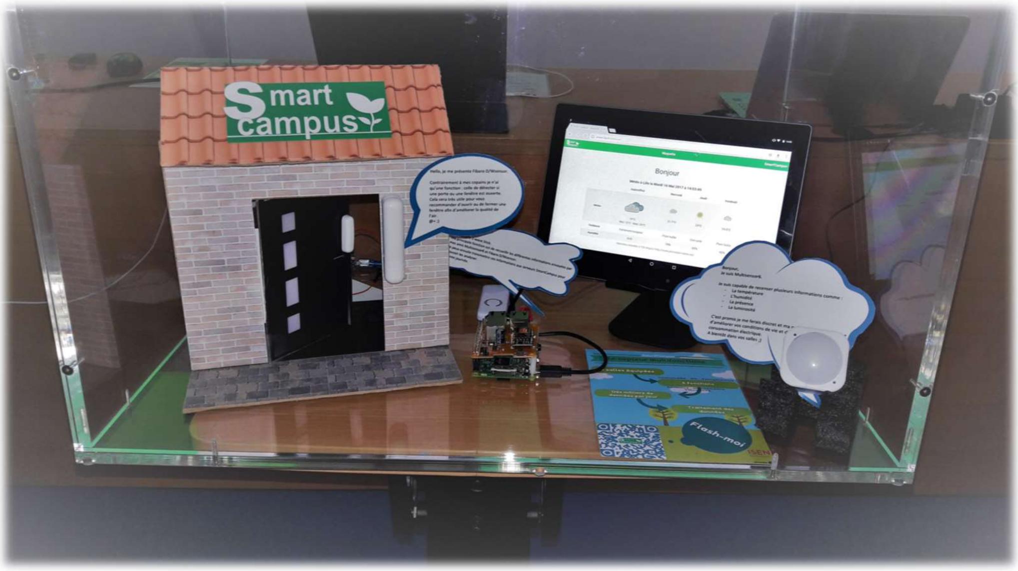

Figure 2: test bed of low cost energy monitoring prototype

4. Conclusion and perspectives

The aim of this work was to identify how the staff cope with a smart building and involve them in that transformation.

Moreover, an energetic diagnosis prototype has been designed and deployed in the ISA building. We focused on the hardware and software technology to develop a sensors network, a communication protocol, data storage and analysis, and web development interface. All technologies used on this solution, allow to define a portable and scalable prototype energy building monitoring.

The future developments concern data recording and analysis during a long period of time (some weeks) in order to be able to identify, using a low cost prototype, how the energy is consumed in the building and if a large deployment of sensors could have an important impact in energy savings, and by result a large economic impact.

Moreover, a CO2 sensor will be also used to measure and alert the staff on their quality of life. A HIM interface will be proposed to show which area in the building represents a waste energy (heating or light, door or window open, isolation, the occupants behaviors...).

The central question of our future work is : "where should we put in place energy savings to make the buildings respectful of the occupants and the environment ?". Our response will be the development of massive data processing mixing a data mining algorithms, statistical methods and machine learning techniques.

It should also be noted that much of this work has been dedicated to communication. Indeed, the large part of ISA staff accepted to be actors for deploying the energy monitoring prototype and make this project innovative.