An approach to residential energy savings using IoT and Cloud Computing to provide real-time feedback

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Abstract. In recent years there has been a growing development of applications oriented to energy saving, based on the Internet of Things and cloud computing. These developments have not only economic motivations, but also environmental ones, related to the reduction of greenhouse gas emissions. The energy sector is perhaps the main global contributor to the emissions of these gases. In the present work, the development of a system based on IoT and CC for the monitoring of energy consumption at the residential level is described. It is organized according to the three-tier model: Edge, Platform and Enterprise. At the Edge level, some innovations are proposed, such as indirect energy sensing and the connection of sensors using the electrical network for data communication. Both would enable an agile deployment of the sensor network. The objective of the system is to provide the user with feedback about their energy consumption and certain environmental variables, in such a way that they can manage their energy consumption, while still achieving an adequate level of comfort.

Keywords: Internet of Things, Cloud Computing, Energy Monitoring.

1 Introduction

The emission of greenhouse gases (GHG) is one of the great current problems, due to its consequences on climate change. As part of the actions agreed by almost all countries, inventories of these emissions are made periodically. 53% of GHG emissions in 2016 in Argentina corresponded to the energy sector: 5.1 points due to residential electricity consumption and 7.4 by residential fuel burning [1]. With some variations, this situation is common to different countries. Around one third of the energy in the world is consumed in large public buildings, and in some countries they contribute about 40% of the total consumption [2]. Saving energy not only has an economic impact, but also an environmental one, although the economic saving could be, probably, the main motivation to make more rational consumptions. In this sense, the feedback that users receive about their consumption is a key factor.

Periodic bills for electricity and gas consumption also serve as feedback, but are not as effective in causing changes in consumption patterns. [3] presents a review of several works about the effectiveness that feedback schemes have on consumption patterns. It could be observed that thanks to the feedback, consumption savings of between 5% and 20% were produced. Also, feedback works well if the following conditions are met: delivered regularly; presented plainly and engagingly; tailored to the householder; interactive and digital; capable of providing information by appliance; accompanied by advice for reducing electricity use; associated with a challenging goal for energy conservation. In [4] a review of different schemes for energy consumption monitoring is presented, classifying the measurements as direct and indirect. Its effectiveness in producing energy savings is highlighted and it is observed that when the cost of energy is important, the savings tend to be greater.

In recent years there has been a growing development of applications oriented to energy saving, based on the Internet of Things (IoT) and Cloud Computing (CC). Some proposals deal with the automation of energy management, according to models that try to save energy consumption at the same time as providing well-being to the inhabitants of so-called smart buildings [5] and smart houses [6], while others are oriented towards provide feedback to users, so they can manage smarter their consumption.

IoT aims to connect real world devices, sensors and actuators, in order to gather the generated information and process it to produce actions on it. IoT devices generally have little processing power. CC has virtually unlimited storage and processing capacity. The conjunction of IoT and CC allows the development of complex solutions, with ease of access by users through web interfaces and / or mobile applications. The main companies that offer cloud services are oriented to the world of IoT [7], such as Amazon, Google and Microsoft, although it is also worth mentioning others such as Mathworks [8], which allows combining their analytical tools with IoT.

This paper presents a system for monitoring residential energy consumption, based on a network of IoT sensors with different communication alternatives with the cloud, through a local gateway, which also implements some basic functions. In the cloud, data is processed and information and analysis are generated for the user. An outstanding feature of this project is to take advantage of the power lines to connect the sensors to the local gateway, which implies greater flexibility for their installation. The communication protocol used between the local gateway and the cloud is MQTT [9], while in the proximity network can be used MQTT with those devices that support it or an ad-hoc protocol for the most basic devices.

2 Variables of Interest. Measurement Strategies

In the case of electrical energy, the variables to be measured for a direct measurement [4][9] are voltage and current. The advantage of the direct strategy is that it enables accurate measurement and is suitable for variable power consumption. It requires taking into account electrical safety aspects.

Another possibility is to carry out indirect measurements, for example using acoustic, piezoelectric o luminic sensors, among others. These types of sensors allow knowing the on or off status of certain devices from noise or vibrations. In these cases a standard power or consumption should be considered and then the operating time should be measured. This strategy would also be suitable for non-invasively monitoring boilers, generators, engines, etc.

In addition to energy, it is also necessary to sense other variables, such as exterior and interior temperature, ambient humidity, light intensity, presence of people, etc., which allow knowing the context in which energy is being consumed, so that, as a result of an analysis, the system can provide suggestions to the user, as well as so that the user can decide based on greater quantity and quality of information. As an example: that the heating is not on when the maximum comfort temperature has been exceeded, or when the outside temperature is above a certain minimum.

3 Network Architecture

Industrial Internet Consortium defines a three-tier model for the IoT architecture [10]: Edge, Platform, and Enterprise. Edge collects data from devices through the proximity network. Platform receives, processes and forwards data from Edge to Enterprise and control commands from Enterprise to Edge; it can also offer some non-domain-specific services, such as queries and analytics. Enterprise implements domain-specific applications, decision support systems, and provides interfaces for end users; it receives data from Edge and Platform and sends control commands to Platform and Edge. Fig. 1 shows a simplified schema of the system over the three-tier model.

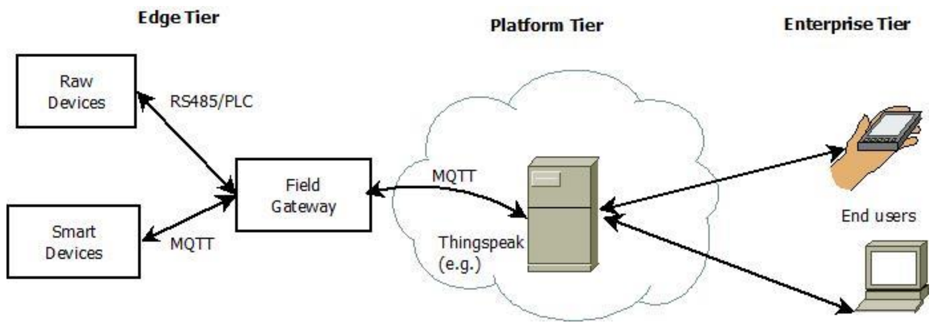

Fig. 1. Structure of the IoT + CC system according to the three-tier architecture.

For this stage, ThingSpeak ™ [8] has been adopted to implement cloud processing. It provides an IoT analysis platform service that allows to add, visualize and analyze live data streams in the cloud. Additionally, it allows to write and execute Matlab ™ code to perform preprocessing, visualization and analysis. ThingSpeak uses channels to store data sent from applications or devices, and data can be read from these channels using HTTP calls and the REST API. You can also use the MQTT subscription method to receive messages every time the channel is updated. However, it would be possible in the future to replace it with another service, even one developed ad-hoc.

Connecting the sensors to the field gateway allows at least two options. In the case of sensors and smart devices, with sufficient memory, processing and networking capacity, they can be connected directly via the local wired or wireless network available on site. On the other hand, for sensors and devices with limited processing and communication capacity, it would be possible to implement an RS-485 network at

9600 or 19200 bit/s, using the electrical cabling as the physical medium. This has the advantage that it does not require additional cabling, simplifying the deployment of the devices.

4 Conclusions and future works

The conjunction of IoT and CC is a valuable tool for energy monitoring and conservation. Based on a certain variety of data collected by the sensors, and the possibility to process a large quantity of them in the cloud, it is possible to obtain online information and analysis, to support decision-making aimed at saving energy.
Future work will continue with the analysis and testing of different indirect measurement strategies, aimed at facilitating the deployment of the sensors, as well as progress in the design of an ad-hoc platform for the storage, processing, analysis and visualization of information.

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