# User Role in IoT-based Systems

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***Abstract*—Currently, in the paradigm of the Internet of Things (IoT) there is a novel strategy to experiment from the human centric perspective whereby the users are the owners of the rules operating smart things. As members of an IoT ecosystem, users inform about their needs and desires, and provide feedback within a networked intelligence to jointly improve their individual ability to rule the actuators of the system at their service. In this paper, we propose an example of a user-centric IoT system in the smart buildings field, in which energy saving is achieved because users behavior aspects are considered for the management of the buildings' infrastructures. An important aim of our user-centric building management system is to bring user role in the loop of the operation system. This platform has been deployed in an office which is a real case of smart building. Experimental tests have been carried out to assess the energy saving derived from considering a user-centric management. The first experimental stages of this system already reflect energy saving of about 23.12% respect with the energy consumption associated to previous periods with similar context conditions.**

***Keywords*—*User-Centric; IoT; Smart Buildings; Energy Efficiency.***

## I. INTRODUCTION

Internet of Things (IoT) can be broadly defined as a global network infrastructure linking uniquely identified physical and virtual objects, things and devices through the exploitation of data capture (sensing), communication and actuation capabilities [1]. The underlying infrastructure of virtually represented "things" in an Internet-like structure includes existing and evolving Internet and network developments. Emerging services and applications will be characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability. Thus, IoT represents a key enabler for smart environments. Potential uses of IoT include the home environment, smart city and health monitoring devices, among others.

The initial roll out of IoT devices has been fueled primarily by industrial and enterprise centric cases. However, their exploitation potential for smart services that address the needs of individual citizens, user communities, or society at large, is limited at this stage and not obvious to many people. Unleashing the full potential of IoT means going beyond the enterprise centric systems and moving towards a user inclusive IoT, in which IoT devices and contributed information flows provided by people are encouraged. This will allow us to unlock a wealth of new user-centric IoT information, and a new generation of services of high value for society will be built. In this sense, the main strength of the IoT paradigm is the high impact that it will have on several aspects of everyday-life and behavior of users.

In this paper we focus on presenting the main features of smart systems based on IoT from an end-user perspective, making a special attention to the importance of active participation of individuals as corner-stone to achieve the expected goals of the services proposed. Following this approach, we propose a user-centric application in the context of smart buildings, where user participation with the system is fundamental to achieve energy saving while optimum comfort conditions are provided to users. This proposal is based in a holistic platform based on IoT that is able to gather information of sensors deployed in the building as well as control actuators such as heating/cooling (HVAC) systems and lighting appliances. To carry out such control actions, an intelligent management subsystem is implemented over the building automation platform, which takes into account both sensed data of user context and data flows coming directly from users (through their interaction with the system, data sensed by their personal devices such as their smart phone, etc.). To assess and validate our proposal of smart system, we present the deployment carried out in a real bank office where tele-monitoring and control actions are implemented to achieve energy saving and user comfort satisfaction. The tests performed so far already show good performance of the system according to the requirements and goals targeted.

The structure of this paper is as follows: Section II describes the user-centric perspective of pervasive services offered by smart systems. Section III presents our proposal for an intelligent management system integrated in an automation platform based on IoT, where the goal is to provide user-centric comfort conditions while ensures the energy sustainability of the building. Section IV details the scenario chosen to deploy the system as well as the first experimental evaluation carried out and results obtained in terms of energy saving. Finally, Section V offers conclusions and a description of future directions of our work.

## II. USER PERSPECTIVE OF SMART SYSTEMS

Today, individuals produce the majority of content on Internet. Users and their personal smart devices represent an important contributor for the generation of most of the IoT content as well. A good example of this trend is Crowdsourcing [2]. This shows that IoT is not just passive technology but also something that gives people new ways to interact with the world. In this way, people understanding and active participation within an IoT eco-system are fundamental to make smart and sustainable environments a reality. The ultimate limit and scope of the IoT is demonstrated by the *Sensing Planet* idea. Here, enormous globally distributed sensor grids capture all natural processes and store them in the cloud. The assumption is that people can analyze, predict, act and prevent

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situations thanks to the huge amount of available data under their control. Nevertheless, a variety of technological socio-economic barriers still have to be overcome to enable such inclusive IoT systems.

Reviewing the recent literature we can identify two approaches to address citizen's concern in the development of the IoT. On the one hand, researchers have developed concrete IoT products that benefit ordinary people [3]. On the other hand, the active role of the end-user in shaping the IoT has been also stressed. For instance, in [4] it is argued that giving end-users the tools to create and invent IoT applications is a way to ensure that people's concern will be adequately addressed. Other example is given in [5], where authors demonstrated how empowering end-users in buildings IoT in a do-it-yourself trend can elevate users' experiences. In [6], it is stated that by providing users with suitable toolkits it is possible to shift innovation from companies to end users.

But to ensure that end-users can be capable of producing and disseminating innovations it is also needed to ensure that they can effectively communicate and distribute their ideas, goals and products. Therefore, providing user with development tools is not enough, but also human perception of IoT is critical for a successful uptake of IoT in all areas of our society. Perceived levels of trust and confidence in the technology are crucial for forming a public opinion on IoT. This is a real challenge for IoT solutions, which are expected to behave seamless and act in the background, invisible to their users.

In order to ensure a wide scale uptake of IoT in all areas of society, architectures and protocols of an inclusive IoT eco-system must be simple and provide motivation for every citizen to contribute an increasing number of IoT devices and information flows in their households, this way making them available to their immediate community and to the IoT at large. As conclusion, from a user-centric perspective, users should be both the final deciders and the system co-designers in terms of feedback conditioning future goals (i.e. the services provided by IoT systems) and contributions to the software issuing these goals.

Bearing all these aspects in mind, it can be noted that for particular individuals one of the most relevant impacts of IoT applications is present in buildings, since they affect users quality of life and work. In next sections we focus on analyzing the IoT buildings context from a user-centric perspective.

## III. A USER-CENTRIC BUILDING MANAGEMENT SYSTEM

Smart buildings should prevent users from having performed routine and tedious tasks to achieve comfort, security, and effective energy management. Sensors and actuators distributed in buildings can make user's life more comfortable; for example: i) rooms heating can be adapted to user preferences and to the weather condition; ii) room lighting can change according to the time of the day; iii) domestic incidents can be avoided with appropriate monitoring and alarm systems; and iv) energy can be saved by automatically switching off electrical equipment when not needed, or regulating their operating power according to user needs.

On the other hand, it is noticeable the current concern for achieving energy efficiency in buildings. National governments, industries and citizens worldwide have recognized the need for a more efficient and responsible use of the planet's resources, and new energy and climate goals have already been adopted accordingly, for example the EU's 20-20-20 goals[1]. To date, real-time information about the energy consumed in a building has been largely invisible to millions of users, who had to settle with traditional electricity bills. Now, thanks to IoT deployments, there is a huge opportunity to improve the offer of cost-effective, user-friendly, healthy and safe products for smart buildings, which provide users with increased awareness (mainly concerning the energy they consume), and permit them to be an input of the underlying processes of the system.

According to [7], achieving energy efficiency in buildings requires solutions in the following fields:

- **Automation systems**. Automation systems in smart buildings take inputs from the sensors installed in corridors and rooms (presence, light, temperature, humidity, etc.), and use these data to control certain subsystems such as HVAC, lighting or security. These and more extended services can be offered intelligently to save energy, taking into account environmental parameters and the location of occupants.
- **Monitoring and consumption feedback**. Monitoring building status and providing users with energy consumption feedback is necessary for energy saving and should be used as a learning tool.
- **Economic strategies**. Finally, an intelligent management system must provide proper adaptation countermeasures for both automated devices and users, with the aim of satisfying the most important comfort and energy efficiency requirements of buildings. On the one hand, a suitable comfort level involves guaranteeing the thermal, air quality and illuminance requirements of occupants, while, on the other hand, energy savings need to be addressed by establishing a tradeoff between comfort measures, the energy resources required and the cost associated with the solution proposed.

As regards building automation systems, many works in the literature address this concern. For instance, a relevant example is the proposal given in [8], where the authors describe an automation system for smart homes over a sensor network. The work presented in [9] is also based on a sensor network to cope with the building automation problem, but this time the messages of the routing protocol include monitoring information of the building. On the other hand, the number of works in the literature addressing energy building management systems using automation platforms is more limited. In [10] for example, a reference implementation of an energy consumption framework is given to analyze the efficiency of a ventilation unit. In [11] the deployment of a common client/server architecture focused on monitoring energy consumption is described but without performing any control action. A similar proposal is found in [12], but with the main difference that it is less focused on efficiency indexes, and more on a cheaper and practical solution to cope with a pilot

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[1] www.ec.europa.eu/clima/policies/package/index_en.htm

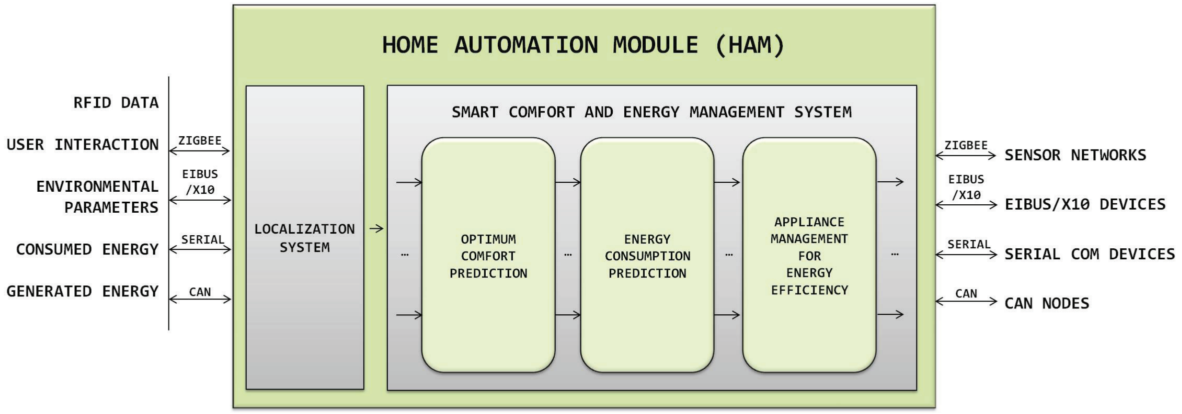


Figure 1. Schema of the modules composing the intelligent management system for energy efficiency of buildings

deployment to collect the feedback from users and perform the actions necessary to improve the system behavior. Thereby, among the works proposed, none is able to exploit completely every IoT capability offered from a user-centric perspective.

In this paper we present our solution of Building Management System (BMS) based on an automation platform following an IoT approach, and an intelligent management subsystem in charge of processing all data gathered to make decisions for controlling main automated appliances distributed through the building and involved in its energy consumption, and considering user intervention every time.

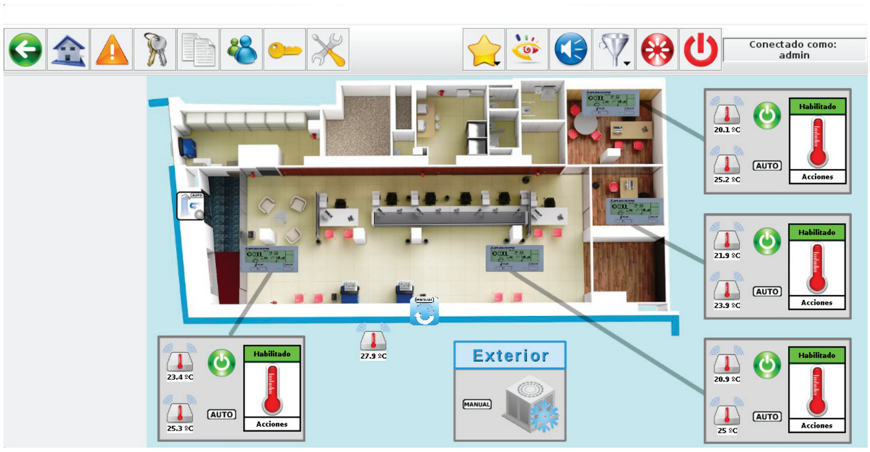
Our base automation platform is based on the *City explorer* solution, whose main components were presented in detail in a previous work [13]. City explorer gathers information from sensors and actuators deployed in the building, and it is responsible for monitoring environmental parameters, gathering tracking data about occupants, detecting anomalies (such as fire and flooding among others), and it is able to take actions dealing with key efficiency requirements, such as saving power or water consumption. The main components of City explorer are the network of Home Automation Modules (HAM) and the SCADA (Supervisory Control And Data Acquisition). Each HAM module comprises an embedded system connected to all the appliances, sensors and actuators of various spaces of the building. These devices centralize the intelligence of each space, controlling the configuration of the installed devices. Additionally, the SCADA offers management and monitoring facilities through a connection with HAMs. Sensors and actuators can be self-configured and controlled remotely through the Internet, enabling a variety of monitoring and control applications. User interaction with the system is carried out through the control panels installed in the building, or a user restricted access to the SCADA view through Internet.

On the other hand, our intelligent management subsystem for comfort and energy efficiency uses a combination of techniques based on behavior-centred mechanisms and computational intelligence for auto-adapting its operation [14]. This way, it is necessary to consider the data provided directly by users through their interaction with the system, since they can change the comfort conditions provided them automatically and, consequently, the system can learn and auto-adjust according to such changes. This subsystem is integrated in the back office part of the City explorer platform. Decisions taken by this module are reflected on the actuators deployed in the building, such as the heating/cooling units and electric lights. We base our energy performance model of buildings on the CEN standard EN 15251 [15], which specifies the design criteria to be used for dimensioning the energy system in buildings, establishing and defining the main input parameters for estimating building energy requirements and evaluating the indoor environment. In addition, our comfort management mechanism is based on the models for predicting the comfort response of building occupants described in [16]. Thus, taking into account all these criteria, we define the input data of our system, which are showed in Figure 1.

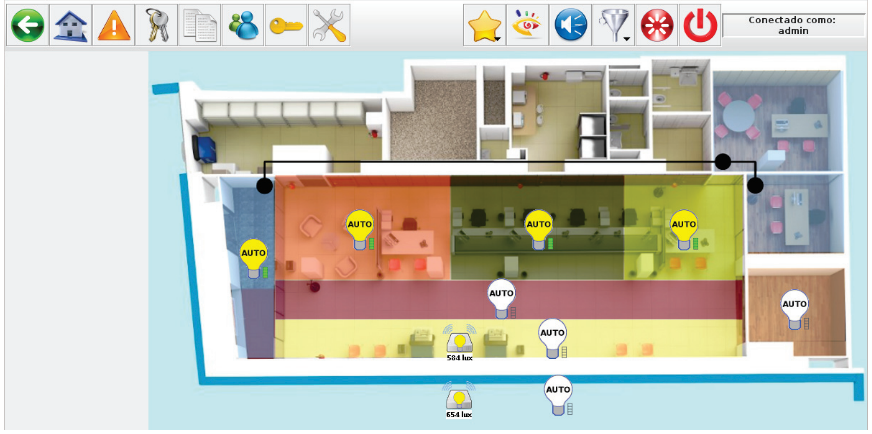
As can be seen in Figure 1, an important prior issue to be solved is the indoor localization problem, since apart from environmental data, user identification and location data are also required to provide customized indoor services in smart buildings. Therefore, information about the number, location and identity of occupants, and even on their activity levels, are needed to adapt the comfort conditions provided in the spaces where occupants stay. Such comfort adaptation is performed through the individual management of the automated appliances in charge of providing service in such areas. In this way, it is possible to carry out control decisions and define strategies to minimize the energy consumption of the building depending on user presence. For this reason, we implemented an indoor localization system that provides positioning data of occupants by using RFID (Radio-Frequency Identification) and IR (Infra-Red) sensors deployed in the building, such mechanism was presented in [17].

## IV. DEPLOYMENT AND ASSESSMENT

In this section we present one of the real deployments of the smart system described in this work. The reference building selected, where City explorer is already installed and working, is a real office of a Spanish bank where energy saving and tele-monitoring are the goals to achieve. The main management actions are focused on controlling HVAC and lighting appliances of such office. In this context, our system has already been evaluated and validated in terms of energy saving and users satisfaction regarding to comfort conditions provided to them. Figure 2 depicts the automated floor of the reference building. This screenshot has been obtained from our SCADA-web, which offers the possibility of consulting



(a) SCADA-web view showing some HVAC automation actions



(b) SCADA-web view showing some lighting automation actions

Figure 2. Rules implemented through the SCADA-web over the automated floor of the reference smart building

any monitored data from the different sensors deployed in the building.

As regards the monitoring and control capabilities, data involved in energy and comfort services comprise the input data of the intelligent system integrated in the HAM installed in the target scenario. On the other hand, separate automation functions for managing lighting and HVAC devices distributed are also provided by the HAM unit installed there. Therefore, it is possible to minimize energy consumption according to the actions suggested by the management system allocated there, and considering user interactions with the system through a control panel or the SCADA-web access of the system.

Taking into account the lights and HVAC appliance distribution in this environment, we can distinguish different target regions where user location problem must be solved to provide occupants with customized comfort conditions according to both their needs and preferences. For such regional divisions, it is necessary to identify the office spaces where people stay, and depending on the expected activities carried out there (people waiting to be attended, office tasks, etc.), estimate the associated lighting and thermal requirements. Therefore, the lighting and HVAC appliances installed in this office must be managed according to the information from the user allocated in each target region and the environmental parameters sensed in the room (lighting, temperature, ventilation and humidity for this study case). Then, all information sensed is gathered in real-time and is available through City explorer. Finally, the intelligent system controls the different settings for the appliances which provide service to occupants.

For the evaluation and validation of our system, we have completed 34 days of the system operation and measurement, so this time is the baseline period used to assess the system performance.

Taking into account the user-centric approach of our system, during our experiment the office's owners could define their own strategies to control any appliance and/or monitor any specific parameters sensed by the system. As regards user interactions with the system to communicate their comfort preferences and energy control strategies, City explorer lets users explore monitored data by navigating through the different automated areas or rooms of the building, and its intuitive graphic editor also allows users to easily design any monitoring/control tasks and/or actions over the actuators (appliances) deployed in the office. The setting of the overall system can also be carried out by users using City explorer, and with no any need to program any controller by code. In this way, it is possible to set up the whole system by simply adding maps and pictures over which users can place the

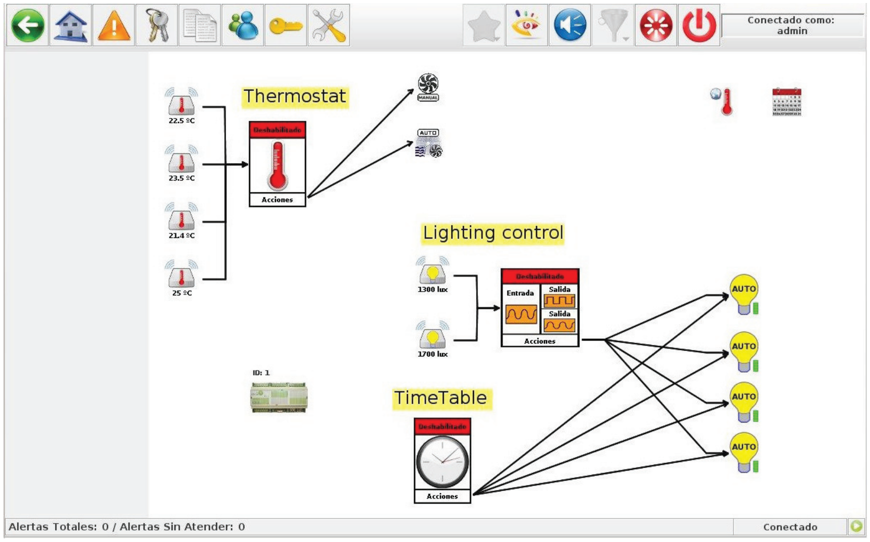


Figure 3. Example of rules defined through the City explorer's editor

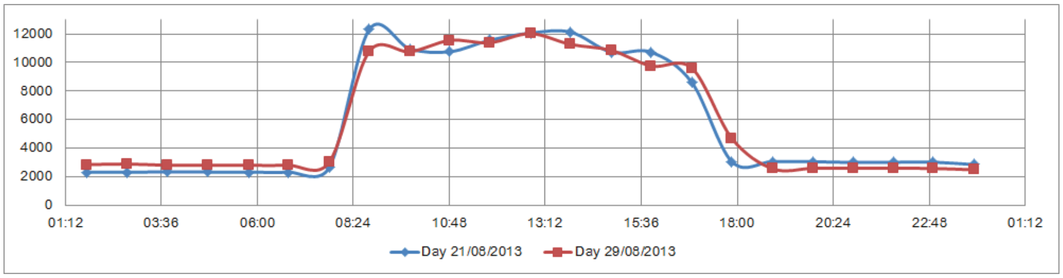


Figure 4. Energy consumption (W/h) during two normal working days with the building management system in operation

different elements of the system (sensors, HAM units, etc.), and design monitoring and control actions through arrows in a similar way to that in which a flowchart is built. Therefore, our system gives users integral control of any aspect involved in the management of the building. An example of the graphic editor of City explorer, in which some rules are defined for the management of the reference office is shown in Figure 3.

It is clear that the environmental conditions and user behavior during both time periods were not exactly the same, so there is a degree of uncertainty concerning the results obtained. But during both periods considered, the occupants' daily routines were very similar and the weather conditions did not suffer any abrupt change, with temperature values between $22^o$ and $28.5^o$. Bearing in mind all these aspects, and despite the relatively short time of evaluation, we have already achieved a relevant mean value of energy saving of 23.12% associated to the cooling and lighting services provided during the operation time of the building management system proposed in this paper.

In Figure 4 we show the energy consumption evolution during two ordinary working days belonged to the system operation period. We can notice how the energy consumption is higher during the working hours of the office, since more appliances were involved to provide users with comfort conditions. We compare the energy consumption in this office during such baseline period with respect the energy consumption of the same time period of the previous month, when non-automation actions were carried out. During the system operation it displayed real time energy usage in kW/h, cost of the energy usage, energy saving tips, energy usage history (hourly, daily, monthly), etc. through both SCADA-web and the control panel installed in the target office.

## V. CONCLUSION

The proliferation of new ICT solutions such as IoT represents new opportunities for the development of intelligent services to achieve more efficient and sustainable environments. Nevertheless, to effect positive ecological behavior changes, a more user-driven approach is needed, whereby design needs are accompanied by analysis on user behavior and motivations. However, to date, studies have tended to bring users into the loop after the design is completed, rather than including them in the system design process.

In this work, we propose a platform which is powered by IoT capabilities and forms part of a novel context-and location-aware system. This system deals with the issues of data collection, intelligent processing for saving energy according to user comfort preferences, and actuation features to modify the operation of relevant indoor devices. An essential part of our intelligent management system is users involvement, through their interactions and their associated data (identity, location and activity), so that customized services can be provided.

The applicability of our system has been demonstrated through an instantiation in a real bank office like case of smart environment. The first validation of our system in such context already demonstrates that users undergo immediate behavior changes related with how they realize about what are their comfort needs and how to properly use the appliances in charge of their requirements. Mean energy savings of about 23.12% have already been achieved during the time period that the system has been in operation following the user-centric approach introduced in first sections of this paper.

Further experiments are being carried out to analyze each of the different pieces that make up our system, for instance the impact of each input data in the system performance. Finally, we are experimenting with mobile crowd-based sensing techniques for gathering data from occupants' personal devices, since such information will be able to complement the data obtained by the system.

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