GReSBAS project: A gamified approach to promote more energy efficient behaviours in buildings

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Abstract

The GReSBAS project (2016-2019) aims to enable the active participation of buildings in DR programs through gamified competition between building owners. In case of large buildings, gamified competition can be established within the building for its occupants, for instance having different floors of the building competing between them. This approach will allow building owners to reduce electricity costs and increase energy efficiency by motivating/rewarding building occupants for participating in DR programs.
The concepts and tools developed under GReSBAS will be tested in two demonstration sites: a corporate building in Portugal and a residential building in Turkey.
This paper presents the Portuguese demonstration site and describes how the energy consumption, temperature and building occupancy data will be collected, processed and used by the tools developed in GReSBAS.

1. Introduction

The growing energy demand poses new carbon based challenges to our society and to the environment. Improved Energy efficiency is one of the initiatives of the European Commission to achieve the European Union energy and climate change policy objectives. As such, it is an integrated part of a long-term growth vision embedded in the Europe 2020 Strategy. Additionally, energy efficiency is the aim of one of the 20-20-20 Europe 2020 targets [1]. There is therefore a strong commitment at EU level to integrate smart grid technologies that trigger energy efficiency and to speed up the stakeholder adoption of these technologies. GReSBAS will contribute to achieving the above aims through its innovative and comprehensive ICT and human factors-based solution, consisting of a gamification platform for buildings' users, which can be used by building owners, aggregators, energy retailers, ESCOs or even network operators, enabling them to trigger positive behaviour change within the various elements of the energy user community [2].

The core objective of GReSBAS is to promote, stimulate and deliver energy efficiency through behavioural change. To encourage a more efficient energy utilization and a more responsible consumer behaviour, the gamification platform will be used to motivate behavioural change by fostering awareness and consumer engagement through a pervasive application that analyses context, sends personalized messages and manages gamified peer competition and feedback, as shown in Fig. 1.

The gamification platform will be embedded in a broader ICT-based platform for energy efficiency with an interactive energy management system, which will aid interested stakeholders optimizing "when and at which rate" energy is to be buffered and consumed, with several advantages, such as reducing peak load, maximizing local renewable energy consumption and delivering a more efficient use of the resources available in individual buildings or blocks of buildings. To maximize benefits, this system will also interact with the buildings' automation systems, whose main goal will be managing, in an optimal manner, all the controllable devices available in the buildings' premises, such as HVAC systems and thermal loads, taking into account equipment technical restrictions, comfort levels and indoor air quality requirements.

The approach to motivate behaviour change is made by intrinsically motivating the user to change procedures and take advantage of opportunities to improve energy efficiency without compromising the comfort level and autonomy. In order for the user to feel in control, the application will analyse the users' context and past behaviour to choose the right moment to introduce advice notices.

The GReSBAS developments will be demonstrated in two regions: a corporate building in Porto, Portugal, and a residential building in Istanbul, Turkey. This paper presents the Portuguese demonstration site and describes how the energy consumption, temperature and building occupancy data will be collected, processed and used in GReSBAS.

2. Demonstration site in Portugal: Corporate building

The demonstration site in Portugal is a corporate building: the INESC TEC headquarters located in the city of Porto. It consists of two contiguous buildings, with a very similar structure. Both buildings have six floors and host a 'smart grids and electric vehicles' laboratory infrastructure [3]. Besides the laboratory, the building has two auditoriums, a bar and several offices and open spaces. The building has approximately 400 daily users.

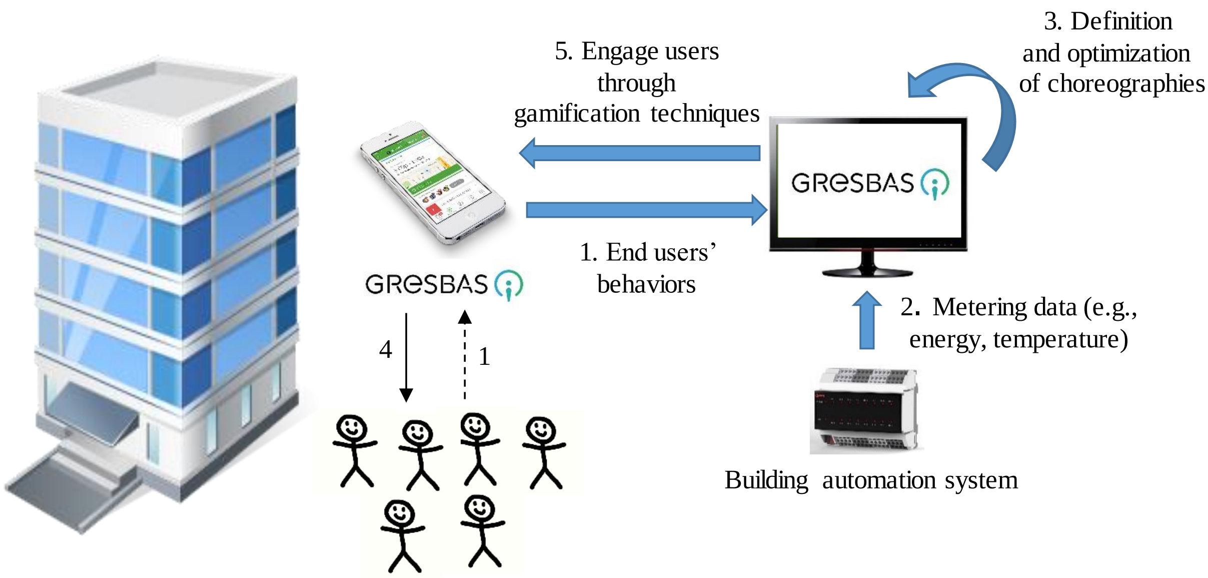

Fig. 1. GReSBAS approach for corporate buildings.

To accomplish GReSBAS objectives, a building monitoring system was installed which includes a sub-metering system with sensors for measuring energy consumption in real-time in more than 160 points and several temperature sensors per floor.

The building incorporates a very extensive set of loads. It is equipped with a HVAC system that is centrally controlled, 4 lifts, 3 server rooms (with about one hundred servers), ca. 400 personal computers, coffee machines, water machines, refrigerators, printers, lights, among others.

The laboratory infrastructure includes 2 electric vehicles, 4 charging points, several storage devices and PV panels.

The factsheet of the demonstrator is shown in Fig. 2.

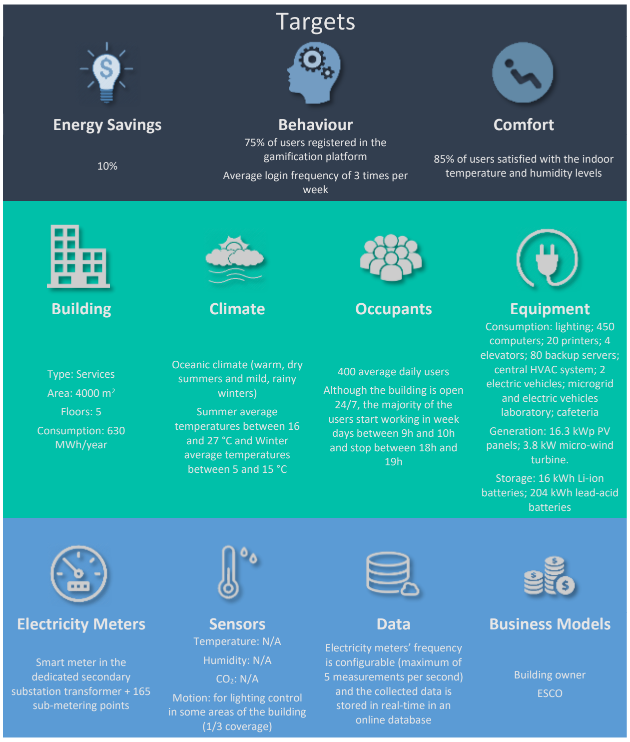

Fig. 2. Factsheet of the Portuguese demonstrator

3. Sub-metering System

The sub-metering system consists in three parts: energy meters, gateways and a server. This equipment is used to measure the energy consumption in the most relevant circuits of the building. The energy meters are equipped with three current transformers (one per phase) and allow obtaining the following information:

- Active power
- Active energy
- Current
- Frequency
- Power factor
- Voltage

At predefined time intervals, that can be configured from seconds to minutes (usually a value between 5 and 15 min is used) these meters store measurements and then send it to a gateway, as shown in Fig. 3. This gateway has the main function of conveying the meter measurements to the server (where the data will be permanently stored). The gateway are required since the meters use PLC (Power-line Communication) technology and the server only communicates using TCP/IP (Transmission Control Protocol / Internet Protocol), commonly known as the computer network. This network uses the infrastructure already implemented.

The server is a virtual machine running a Linux operating system, a MySQL database to allow persistently store all collected data, a JAVA plugin that will perform the communication between the gateways and the PERL scripting language to allow carrying the data from the plugin to the DB.

Due to the need of ensuring maximum security and system replacement as fast as possible, in case of failures, it was decided to implement a virtualization system. This system allows not only running multiple virtual machines (creating a better use of resources) but also an extra guarantee in case of failures that require to restore a previous backup.

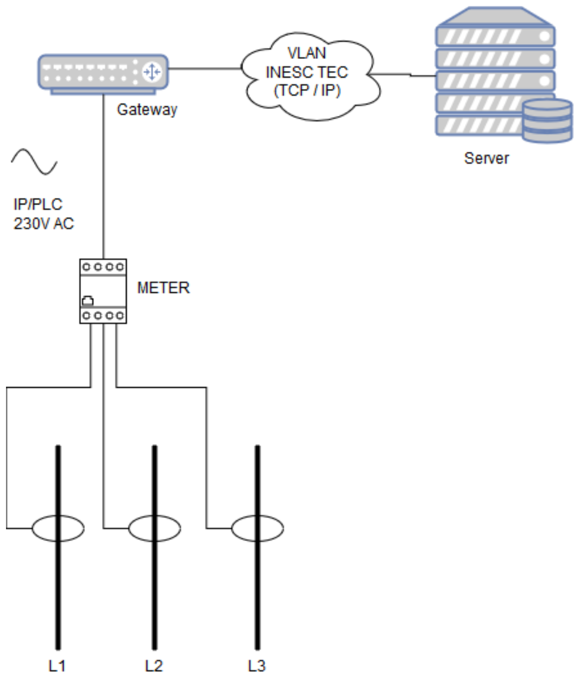

Fig. 3. Diagram of the connections between the equipment of the energy measurement system

The virtual machine created uses a JAVA plugin that collects information from all gateways. This plugin temporarily stores information in object format and can be accessed through an HTTP REST API.

The current capacity of the server is about 250 thousand samplings, which, when divided by the approximately 170 meters that make up the total installation, allows to store temporarily about 1500 measurements per meter. If each meter provides a measurement every 15 minutes, this allows to store data of ca. 15 days.

Through a URL, it is possible to obtain the data of each meter in JSON format. To safeguard this information a PERL script has been developed that accesses the indicated URL, extracts this information and inserts it in the DB for permanent storage. This process is shown in Fig. 4.

To avoid duplicate values, whenever you access the REST API to get the data, they are automatically deleted from the server. This script will run automatically at one-minute intervals. This enables the number of data pending on the REST server to be as short as possible and the data available as quickly as possible to be used for the gamification application.

A simplified version of the DB structure is shown in Fig. 5. The *Gateway* table stores information about gateways such as macaddress or IP. It also has the indication of its location because all the gateways are in or near electric switchboards. The *Device* table stores information about the meters where only the macaddress is stored and where they are installed. The *typeOfMetering* and *phaseOfMetering* tables are tables only to ensure data consistency, which data will all be stored in the *Metering* table. This table will store all the records that come from the plugins and will be treated and analysed for use during game implementation.

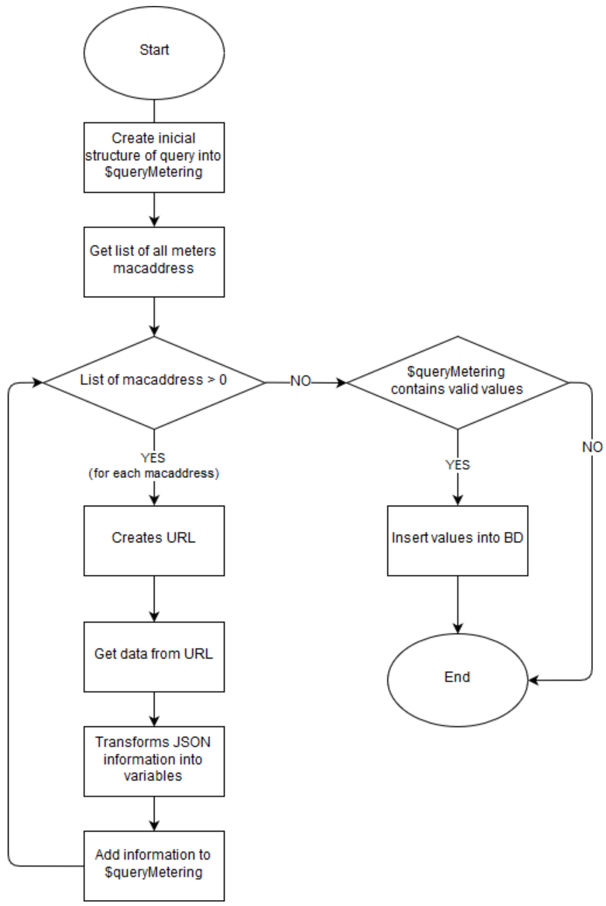

Fig. 4. Flowchart of the script to permanently save meters' data in the DB

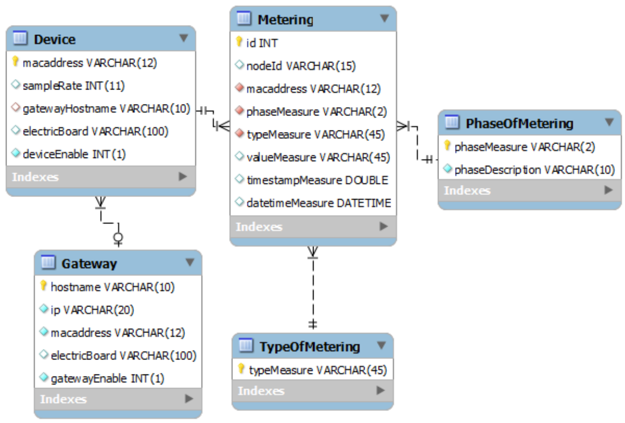

Fig. 5. Diagram of the DB to persistently store data from the energy metering system

4. Gamified approach to induce energy behavioural change

The proposed gamified approach exploits the concept of choreographies. A choreography is a set of interactions and events performed by humans that take place in a given time and space with well-defined objectives and rules [4]. The gamified approach relies on the definition and optimization of choreographies with the aim of motivating behavioral changes that contribute to reduce energy costs.

As previously referred, Fig. 1 shows the general approach of the GReSBAS project for corporate buildings. The first step consists on collecting users' data (e.g., behaviors) through mobile applications and metering data (e.g., energy, temperature) through building automation systems. Based on the collected data, it is possible to map and associate energy consumptions with individual and collective users' behaviors. This association defines a choreography. After the identification of the initial choreographies, the GREsBAS solution computes optimized choreographies (i.e., alternative behaviours) with the objective of identifying opportunities to reduce energy costs. Finally, gamification techniques [5, 6] are used to engage users into more cost effective behaviours.

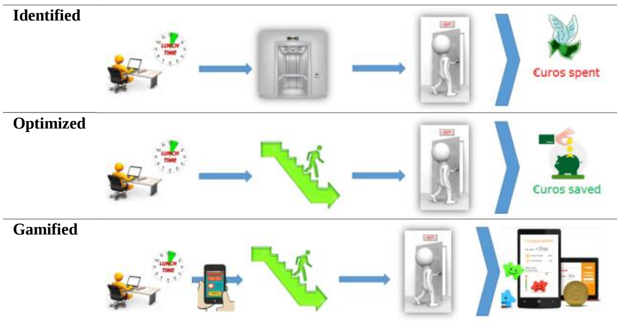

Fig. 6. Elevator choreography process

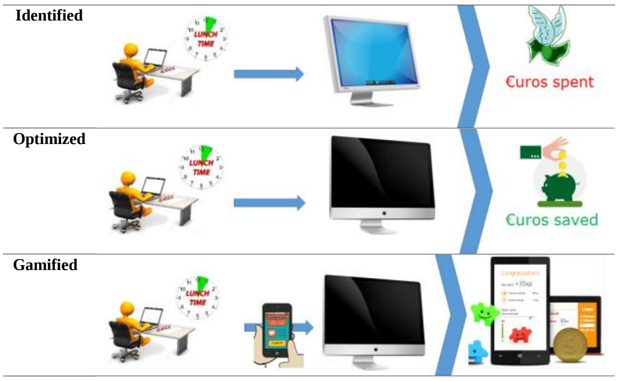

Fig. 7. Monitor choreography process

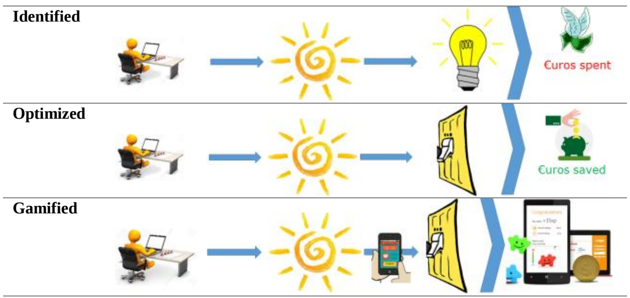

Fig. 8. Lighting Choreography process

Fig. 6, 7 and 8 show the gamified process of two different choreographies from the identification until the gamification phase. Fig. 6 presents the elevator choreography. The GReSBAS solution identifies that the user usually takes the elevator when goes to lunch. Afterwards, the GReSBAS solution computes and identifies an alternative behavior that may contribute to reduce energy costs. To engage and promote behavior change, the GReSBAS solution exploits gamification techniques. The same approach can be applied to other behavioral choreographies as the one presented in Fig. 7 and Fig. 8.

5. Conclusions

This paper presented the GReSBAS project, which aims at enabling the active participation of buildings in DR programs through gamified competition. The gamified approach that will be used in the project to induce energy behavioral change was also described. This approach is based on the concept of choreographies, that are a set of interactions and events performed by humans that take place in a given time and space with well-defined objectives and rules.

The main characteristics of the Portuguese demonstration site, a corporate building, were also presented. The gamified approach developed to induce energy behavioral change will be tested in this building with the goal of achieving 10% of energy savings and simultaneously maintaining 85% of the building occupants satisfied with indoor temperature and humidity levels.

To achieve these targets, a complex sub-metering infrastructure was installed in the building. Details regarding data collection, transmission, storage and utilization were also provided.

6. Acknowledgements

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7. References

[1] "Energy Efficiency Strategy: progress towards the 2020 EU target and next steps", 2013.
[2] http://gresbas.eu/gresbas-site/en/
[3] C. Gouveia, D. Rua, F. Ribeiro, L. Miranda, J.M. Rodrigues, C.L. Moreira, J.A. Peças Lopes, Experimental validation of smart distribution grids: Development of a microgrid and electric mobility laboratory, International Journal of Electrical Power & Energy Systems, Volume 78, 2016, Pages 765-775.
[4] G. Kurillo, R. Bajcsy, K. Nahrsted, O. Kreylos, Immersive 3D Environment for Remote Collaboration and Training of Physical Activities, in: 2008 IEEE Virtual Real. Conf., IEEE, 2008: pp. 269–270.
[5] S. Deterding, K. O´Hara, M. Sicart, D. Dixon, L. Nacke, Gamification: Using game design elements in non-game contexts, Proc. 2011 Annu. Conf. Hum. Factors Comput. Syst. (CHI 2011). (2011) 2425–2428.
[6] K. Seaborn, D.I. Fels, Gamification in theory and action: A survey, Int. J. Hum. Comput. Stud. 74 (2015) 14–31. doi:10.1016/j.ijhcs.2014.09.006