OPEN HABITAT. AN OPEN SOURCE TECHNOLOGY DEVELOPMENT PLATFORM FOR THE SMART HABITAT

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ABSTRACT

This paper presents the methodology and most prominent results of a project carried out in 2012 and 2013, the overall objective of which has been to create a complete development platform that enables companies involved in the realm of the Habitat to create innovative products equipped with an array of technological devices aimed at adapting homes to the needs of three specific groups - Children, Seniors and People with Disabilities - with the ultimate aim of improving the quality of life for those users by

facilitating their ability to interact with their homes. This overall objective can be broken down into the following specific targets:

- **To identify the specific needs** of the three groups of users under analysis in various areas related with the Habitat (safety, comfort, health, communications, etc.).

- **To develop a series of products for the Habitat**, equipped with local connectivity and capable of interacting in a common automated environment, as well as being linked via a Communications Platform to a system that enables them to detect pre-defined behaviour patterns. These developments are required in order to define protocols both for communications and for the development of new products.

- **To develop a Communications Platform** with its corresponding open source standards, which guarantee both connectivity with the smart products and sufficient computing capacity to enable any stakeholders in the Habitat to create suitable applications that meet the previously identified needs. The platform will serve as a communications gateway between smart data-capturing products (sensors) and those that perform actions (actuators), and comprises a computer system implemented by Context Modelling techniques. Within such a framework, we have defined the technical requirements that Habitat products must meet in order to connect to the Platform.

The execution of this project has generated a map of applications that companies can use to define their products. A set of interconnected examples were extracted and developed from the map to illustrate the possibilities of such a system of improving the quality of life for the social groups under analysis in each of the habitat sectors involved: ceramics, furniture, textiles, construction and lighting.

1. INTRODUCTION

The Open Habitat project stems from the concept of the Smart Habitat, a new area of work aimed at facilitating the interaction of people with their surrounding environment in such a way as to enable that environment to respond independently to each user's specific requirements.

The project, which is being implemented between 2012 and 2014, aims to create a comprehensive development platform that allows companies dedicated to the Habitat concept to design and create innovative products based on various technological devices that enable homes to adapt to the identified needs of three groups of dwellers - Children, the Elderly and People with Disabilities - with the ultimate aim of improving those users' quality of life by facilitating their ability to interact with their homes.

The following milestones were accomplished during 2012:

- Identification of the specific needs of our target users - children, the elderly and people with physical disabilities. These groups were identified as requiring more innovation and thus having a greater potential for growth.

- Generation of a panel of proposed solutions for the smart home based on the specific requirements identified above.

- Definition of the connection requirements for the devices to be integrated in the system and of the service Application Programming Interface (API) needed for those devices to access the system.

- Definition of the developments and applications to be integrated into the platform.

The following tasks have been earmarked for completion during 2013-2014:

- Completion of the protocol required to develop products designed to meet the specific demands identified for our target users within the Habitat environment. This standard will allow Hypersector companies to generate their own solutions to meet those demands.

- Development of the smart products whose integration in the platform has already been decided on and which will be pre-tested by our target users to assess their usability and functionality.

- Development of an open source communications platform that is accessible to all companies and which should integrate a standard communications protocol and a computer system to enable customised applications to be developed in order to capture data from smart products, to interpret that data and to implement appropriate actions accordingly.

- Definition of the strategies required to provide the platform with environmental intelligence, which includes evaluating the computational complexity involved.

- Development of a prototype demonstration unit that simulates a habitat environment and serves as a technology testing and validation laboratory for the items developed under the project and for future products developed by other actors using the protocols created herein. This demonstration mock-up will comprise a set of products commonly used in the Habitat equipped with the necessary technology for them to interact with the users, either under deliberate user's command or without the user even noticing, as well as an open computing and communications platform where the various newly-developed products can download the data they have captured via a standard protocol.

Finally, the demonstration prototype will incorporate technological validation of all specific devices and software modules created as part of the Control and Communications Platform to manage those devices. The specific objectives to be achieved are:

- The development of protocols to validate the software and hardware applications created within the framework of the project or to be created in the future so that

their functionality for use on the Smart Habitat Control and Communications Platform can be tested.

- The validation of all applications thus developed from the point of view of their technological functionality.

In order to ensure that the newly developed products included in the prototype meet users' expectations and specifications, they will be rated according to the degree of satisfaction expressed by the different groups of users. To do so, the following objectives have been defined:

- To identify the degree of user satisfaction in terms of the products' and the prototype's usability (i.e. ease of use).

- To identify the degree of user satisfaction in terms of the products' usefulness (i.e. ability to meet users' demands in the pre-defined areas) in order to provide greater quality of life for those groups.

The results obtained in the project during 2012, which generally focused on identifying users' needs and developing a Communications Platform, are set out below:

2. IDENTIFICATION OF USERS' NEEDS

The first stage was to **identify** our target users' (children, seniors, and people with disabilities) current and latent **needs and problems** in the home and to generate proposals that respond to the issues identified for each type of user in a Smart Habitat.

The methodology employed is encompassed within the User Oriented Innovation concept based on usage research techniques combined with advanced research techniques in immersive virtual environments.

The **conceptual framework of the project was defined** by analyzing the study situation in general terms and describing concrete situations. All the data necessary to carry out the research were collected by implementing the following activities:

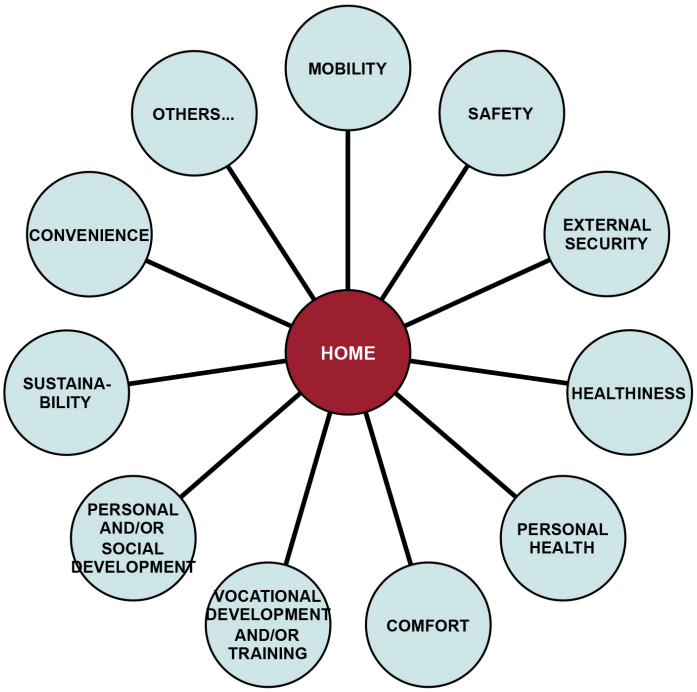
- State of the art: this constitutes the theoretical basis on which the research was based and involved collecting publications about accessibility and actions taken to improve welfare in the home.

- Information was collected from different sources: (2001 Population and Housing Census, Household Budget Survey, Survey of Living Conditions, Census of Disabled Persons ...).

- The available data were then analysed.

On the basis of the variables thus identified, the groups of users to be studied, as well as those groups that attend to them and help them in the home (family, professional caregivers, nurses), were **characterised and quantified**.

Taking the framework of the project and that characterisation into account, the next stage was to **identify the key variables** in the research for each group of users (the elderly, children and the disabled) by drawing up a list of needs under the following parameters:



Map of needs and parameters analysed.

The following is an outline of the potential needs, safety features required to prevent risks, and situations to be dealt with for each of the various parameters thus defined:

- **Mobility-Accessibility**: The need to move freely from room to room and to overcome potential barriers (such as doors, tables, etc.) i.e. not encountering obstacles (furniture, etc.) or barriers that may hinder or impede free mobility or accessibility "to" and "around" the different rooms.

- **Safety**: The need to avoid risk, danger or accidents inside the home. This is linked to avoiding accidents due to possible falls (at the same or different heights) or to prevent tripping (over carpets, unnecessary decorative items, lack of natural or artificial lighting), and generally to preventing physical knocks and injury. This heading encompasses a wide range of possible scenarios: restricted access throughout the home to power sockets or the use of appliances in the kitchen and control of sharp surfaces and also of objects to prevent cuts and wounds inflicted by contact or use of knives, etc.). Special care is also taken in the kitchen with regard to safety related to the emission of gases (carbon monoxide from the boiler or cooker) or particles causing suffocation, exposure to toxic products (chemical powders and their possible ingestion, etc.).

- **External security**: Needs in terms of protection in the home (when the occupant is present) or away from it (when the occupant is absent) against incidents such as: defence against intruders, theft prevention, flood or fire warnings, etc. Of special concern in this respect is access to balconies, terraces, etc. An especially critical scenario are semi-detached and detached houses and villas.

- **Healthiness**: This heading includes situations both outside the home (e.g. the water supply) and those relating to the use made of the home itself or internal risks (waste disposal, garbage collection, etc.). For the purposes of this project, only the internal aspects of the home will be taken into account, which principally relate to matters of hygiene and cleanliness designed to optimise living standards inside the home. It therefore encompasses issues such as the control of ventilation (air movement depending on the season), odours (control of air currents), smoke (ventilation control, etc.). In short, this parameter covers needs in terms of hygiene and seeks to afford protection with regard to healthiness in the home.

- **Personal health**: This refers to the biological protection of home dwellers, to prevent them from becoming ill, to identify disease or to maintain control over those factors that determine and influence personal health. Therefore, it relates to matters concerning medication – of utmost importance with the elderly - and in the case of children, to prevent them from accidentally ingesting drugs. It also involves the provision of telecare (constant monitoring of the patient's illness), telemedicine (patient care in their own home and in a timely manner) and/or (essential) healthcare services. With respect to detecting health problems, it would include measuring body temperature, vital signs, etc.

- **Comfort**: This parameter covers both outdoor situations and situations that are derived from outside but felt indoors. Such outdoor-derived situations refer to neighbours, light, weather, traffic noise, etc. One example is the impact of preventing noise pollution with sound-proofing, the need to control natural light, etc. Actions taken under this parameter are designed to achieve suitable hygrothermal comfort (absence of thermal discomfort: temperatures throughout the home of around 20ºC in all rooms and an optimum relative humidity of between 50-70%). Likewise, it involves actions indoors, such as the need to turn night-time lighting on or off, etc.

- **Vocational development and/or training**: This could be considered as a set of requirements consistent with the specific characteristics of our reference groups. By way of example, it is possible that some of the elderly and disabled persons in the group perform some kind of work classed as "home employment". It also encompasses the engagement in activities aimed at acquiring or improving personal skills (distance learning and/or tele-education).

- **Personal and/or social development**: This refers to needs that enable the dweller to further his/her own personal development. For example, to enjoy one's leisure time, to personalise one's surroundings. It would include avoiding the feeling of personal discomfort or psychological distress, such as, for example, detecting

nightmares, encouraging relaxation and stimulating rest and sleep. It therefore includes minimising physical, psychological and even social tensions.

- **Sustainability**: This heading includes those needs related to the performance of the home's utilities and installations: energy saving, energy efficiency (appliances, lighting, etc.), and also includes aspects such as water consumption, waste recycling or (in some cases) control of CO2 emissions.

- **Convenience**: This includes situations linked to the convenience of one's surroundings and making life "easier" for users (not necessarily our reference groups but for their carers, families, etc..), even though it may not be considered a key requirement. It could include the ability to receive messages about the state of the house or the ability to view rooms or areas remotely while away from home.

Having defined the above parameters, we ran an analysis to define what conditions are considered to already exist and which are ideal (latent) or at least desirable with a view to improving the quality of life. Finally, the process of adapting, converting or modifying the home for the inhabitants living there was analysed:

a. In some cases with regard to the building's physical structures

b. In others, by incorporating environmental intelligence systems or items that improve current standards of living, such as computer systems or communications between sensors, etc.

Having defined and analysed the needs of the various users, the next step was to identify possible solutions in terms of devices and systems that can operate in a given environment to facilitate certain actions, provide information or adapt living conditions to improve comfort. In this regard, the types of target users were assessed, the restrictive conditions of the living and working environments in which they operate were analysed and the specific needs of each of these user-environment combinations were defined.

That information was then used to develop a map of applications for the habitat, which embraces the full range of applications and developments to be carried out in the project and integrated into the open smart monitoring and control platform, whether they are items that are already available on the market (sensors / actuators, emission / detection devices, or other items in the system), or whether they are new applications or tools that need to be developed.

Figure 1 shows the map of applications and the operating scheme for the developments to be used in the demonstration prototype and set up in such a way as to provide a specific solution or application.

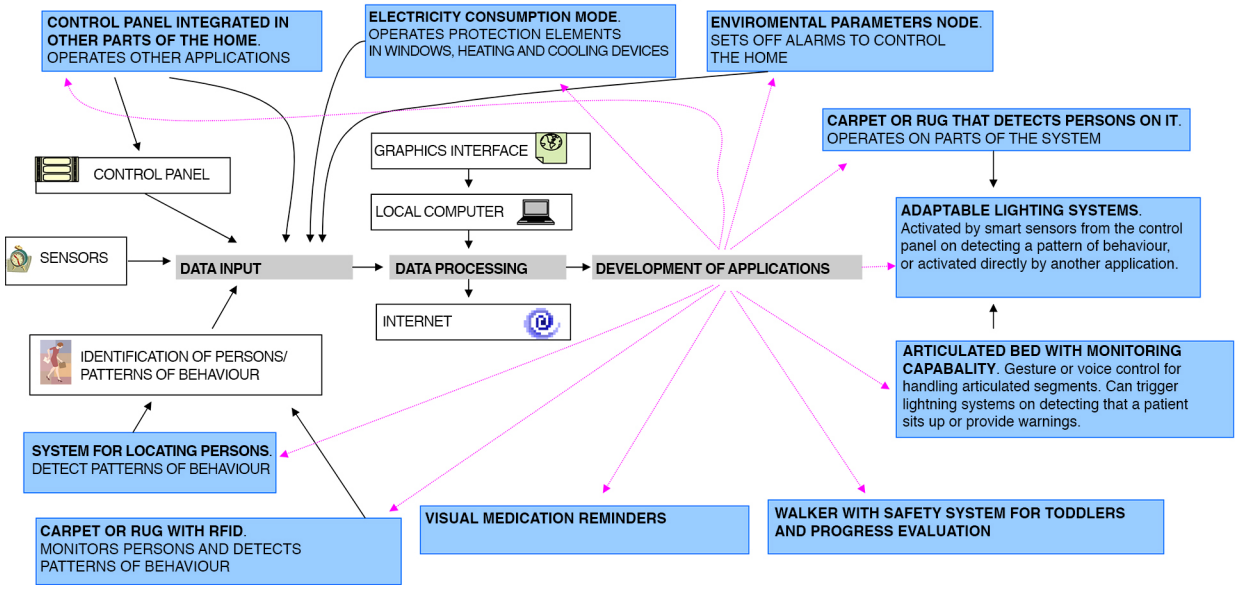


Figure 1. Map of applications.

Once the map of applications had been defined, the next step was to briefly describe the products to be developed and integrated into the platform, paying special attention to the ceramic control panel.

- **Articulated bed with user monitoring system**: This is a household bed that can be used in standard situations for the elderly and/or disabled as well as for bed-ridden patients in home care. The bed has a motorised articulated base that folds in different segments. It is also fitted with devices that enable continual monitoring of a series of physical variables as required, either to detect and analyse specific behaviour patterns or for therapeutic/clinical purposes.

- **Children's walker with activity monitoring**: This is a toddler's walker with various functionalities. The most basic functionality is the detection of dangerous obstacles (unprotected areas where a baby can fall into or through), which triggers a safety feature that would prevent the fall.

- **Camera-based intruder and movement control system**: This system allows you to track people entering the field of view of each of the cameras in the system in real time. By implementing such monitoring, routines can be ascertained and thus abnormal behaviour patterns detected after a certain period of analysis.

- **Location system based on the use of RFID tags**: This is a system that allows people to be located in real time inside a building, in order to define their behaviour using bracelets that emit data about where those persons are located.

- **Self-adapting lighting device**: This is a smart lighting system with different

functionalities that adapts according to the needs of the room where it is fitted and the type of person occupying that room.

- **Electricity consumption node**: This node allows for electric power consumption in the homes of sensitive users (the elderly, children and the handicapped) to be measured and reported in real time.

- **Environmental parameters node**: This node allows for real-time monitoring of various environmental parameters such as: temperature, relative humidity, CO2 concentration, etc. The node will contain several different types of sensors that monitor a series of environmental parameters at pre-set intervals of time and is to be fitted with a number of outputs so that it can control and handle the performance of different items of ambience equipment to adjust those environmental parameters to the desired values.

- **Carpets that detect persons standing on them**: this refers to carpets or rugs that can detect when pressure is exerted on their surface. When pressure is applied on the carpet/rug, that alters its morphology and consequently generates a capacity change. Thanks to those changes, it can detect pressure in the area.

- **RFID rug or carpet**: This is an RFID rug/carpet that also doubles up as a reader of RFID-tagged items. The carpet will be sectioned into different zones so that it can detect the precise location of the tagged item. Thanks to RFID technology's identification capabilities, it enables the tagged item to be tracked and located with accuracy.

- **General Control Panel installed in ceramic cladding**: This is a control panel built into the house's ceramic cladding that will enable both the afore-mentioned applications and any others that are eventually compatible with Open Habitat to be monitored.

Todos estos productos han sido definidos en cuanto a funcionalidad y aspecto. Seguidamente se exponen, a modo de ejemplo, las características exigibles a uno de ellos: el panel de control.

3. GENERAL CONTROL PANEL

3.1. THE PANEL IS REQUIRED TO HAVE THE FOLLOWING **CHARACTERISTICS**:

1. Ease of use.
2. Markings and icons designed according to ergonomic criteria to allow it to be easily read and understood by the groups of people for which it is intended: the elderly and people with disabilities.
3. Buttons large enough to be used by people with upper limb disabilities.

4. Feedback indicators (lights or sounds)
5. Easy to clean and maintain
6. Safe to use
7. The Panel must be easy to fit and remove to enable its data recording to be configured as required.
8. As far as possible, the use of power wiring shall be avoided in favour of batteries, thus ensuring it continues to operate properly in the event of a power cut.

3.2. THE USE OF **CAPACITIVE SENSORS** WILL ENABLE:

1. Activation by proximity requiring no input effort
2. The possibility of integrating switches and dimmers
3. Simple cleaning of the surface as it contains no mechanisms
4. Long-life operation with minimal or no maintenance
5. Easy connectivity to other Open Habitat compatible devices

3.3. IT COMPRISES TWO BASIC TYPES OF FUNCTIONS:

a. Configuration functions: those executed by the caregiver to configure the environment.

b. User functions: Those executed by users (elderly, people with disabilities or users in general).

3.4. PANEL INTEGRATION WILL BE TWO-FOLD:

- Local integration:
  1. Local integration will be via a direct connection to a local processor to avoid gate delays.
  2. It will use the protocols defined in Open Habitat.
  3. It should be capable of operating with both wired and wireless connections.
- Internet integration:
  1. The panel will transmit the actions taken to an internet server.
  2. This server can then perform supervision functions.
  3. It should also be possible to access and interact with the various items via the Internet.

3.5. CERAMIC PANEL DESIGN:

The control panel consists of a ceramic sheet, on the back of which a functional panel will be installed. Icons will be fitted on the visible side of the panel and should be removable so that the panel can be reconfigured to match the specific needs of the target user. The design of the icons used shall be based on ergonomic criteria to allow for easy reading and understanding by the group of persons it is intended for: the elderly and people with disabilities [1][3][4].

For commercial purposes, the panel can be built into any ceramic format available on the market. For the demonstration model, the plan is to use a 3 mm thick fibreglass-reinforced sheet with maximum dimensions of 100x300 cm to be defined in terms of the characteristics of the place where it is to be located.

To ensure accessibility for people in wheelchairs, active areas housing command and control items should be located at a height of between 800 and 1200 mm [2]. On the other hand, to enable adequate reading of texts written in Braille [2], it is recommended that signs be fitted at a height of between 1250 and 1750 mm, although that height can be extended down to 900 mm above floor level. Therefore, for the panel design, we intend to use a range of between 900 and 1200 mm from the floor as per the following diagram:

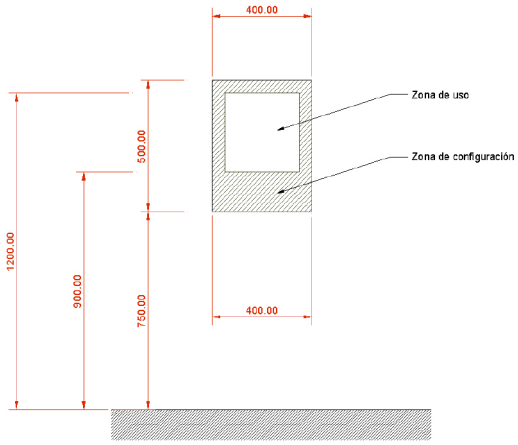


Figure 2. Position of user-configuration areas.

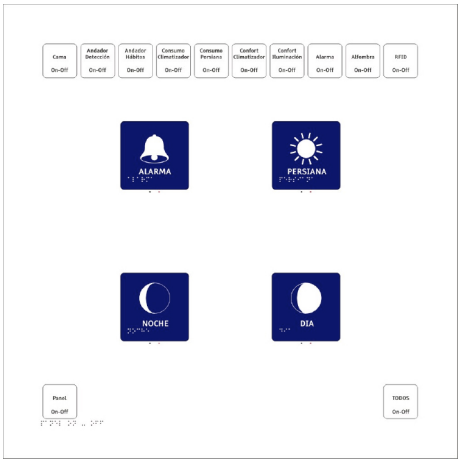


Figure 3. Ceramic panel design.

The panel is to be easily assembled and removed to allow registration and configuration as required. Power cables are to be avoided whenever possible and the incorporation of batteries is planned to ensure autonomy in the event of a mains power failure. Figure 4 shows a conceptual sketch of the ceramic control panel built into the demonstration area.

Figure 4. Demonstration room with built-in control panel.

4. DEVELOPMENT OF THE COMMUNICATIONS PLATFORM

This section deals with one of the main objectives of the project, namely the development of a technology platform that enables these groups' standard environments to be converted into intelligent environments by integrating various technological devices in common areas of the open habitat (floors, walls, furniture, furnishings, etc.).

The control and communications platform in an intelligent environment of these characteristics has to allow for various types of devices and components to connect to the system so they can be configured to perform specific actions. The platform will act as a communications gateway between the smart data-capturing products, i.e. those that contain some kind of sensor, and the ones that perform actions (actuators). It will be equipped with a computer system that processes the data and, in some cases, takes decisions automatically to activate specific devices.

In general, the components connected to the control and communications platform will be wireless sensor networks (WSN), i.e. a set of nodes with standalone sensors, distributed and built into the various items that comprise the environment and which monitor physical or environmental conditions such as temperature, sound, pressure, etc. and transmit the data through the network to a main node or coordinator. Should complex data processing be required, the platform enables the coordinator to transfer data via the Internet, which is thus the primary means of transmitting and controlling that data and therefore the devices themselves. Wireless sensor networks are bi-directional, i.e. a coordinator node can monitor and act on other nodes, either autonomously, when pre-set to do so, or in response to pre-processing on a server connected to the Internet.

In addition to the WSNs, other items can be integrated on the control and communications platform through its Internet connection, such as IP surveillance cameras or smart washing machines, for example. To facilitate the integration in the system of different devices developed as part of this project, the control and communications platform will fulfil two fundamental requirements:

- It should be an open platform in which a wide range of devices with sensors and/or actuators can easily be integrated.

- It should be a scalable platform with a tree structure to which new nodes and items can gradually be added.

Not only should the platform meet the above requirements but it must also include the following features:

- It should enable the various new products to download the data captured from their peripheral sensors, cameras, etc. using a standard protocol.

- It should provide for or enable the integration of suitable computing and data processing tools to analyse the captured data, relate that data to the needs of the target users and automatically take decisions to cover those needs.

- It should be provided with external connectivity to service providers, such as, for example, security services, health care services, etc.

The platform will employ context modelling techniques to provide a layer of reasoning and automatic or semi-automatic behaviour capable of assessing situations and taking appropriate decisions to solve them.

Taking the pre-established features and functionality of the platform into consideration, the outline of this layer of reasoning has been designed on the basis of three major functional blocks:

- A **Database** that structures storage of the data in the control and communications platform. It is based on the data model developed for Open Habitat that represents the physical and logical characteristics of the various components of the system.

- A **Processor** incorporating the required computing and calculation tools to analyse the data collected by the various devices, relate it to the target needs of user groups and take decisions that satisfy those needs. The processor will communicate with the database through a series of functions that access data held on it. That way, the processor can store the information from the capture devices directly or after some pre-processing and retrieve the data it needs to make available to display devices or to perform operations with it and generate alarms or other events.

- An **Event Manager** that "listens" permanently to the processor so that, if a number of conditions are fulfilled, an alarm is generated to trigger action on the database or on one or other of the devices.

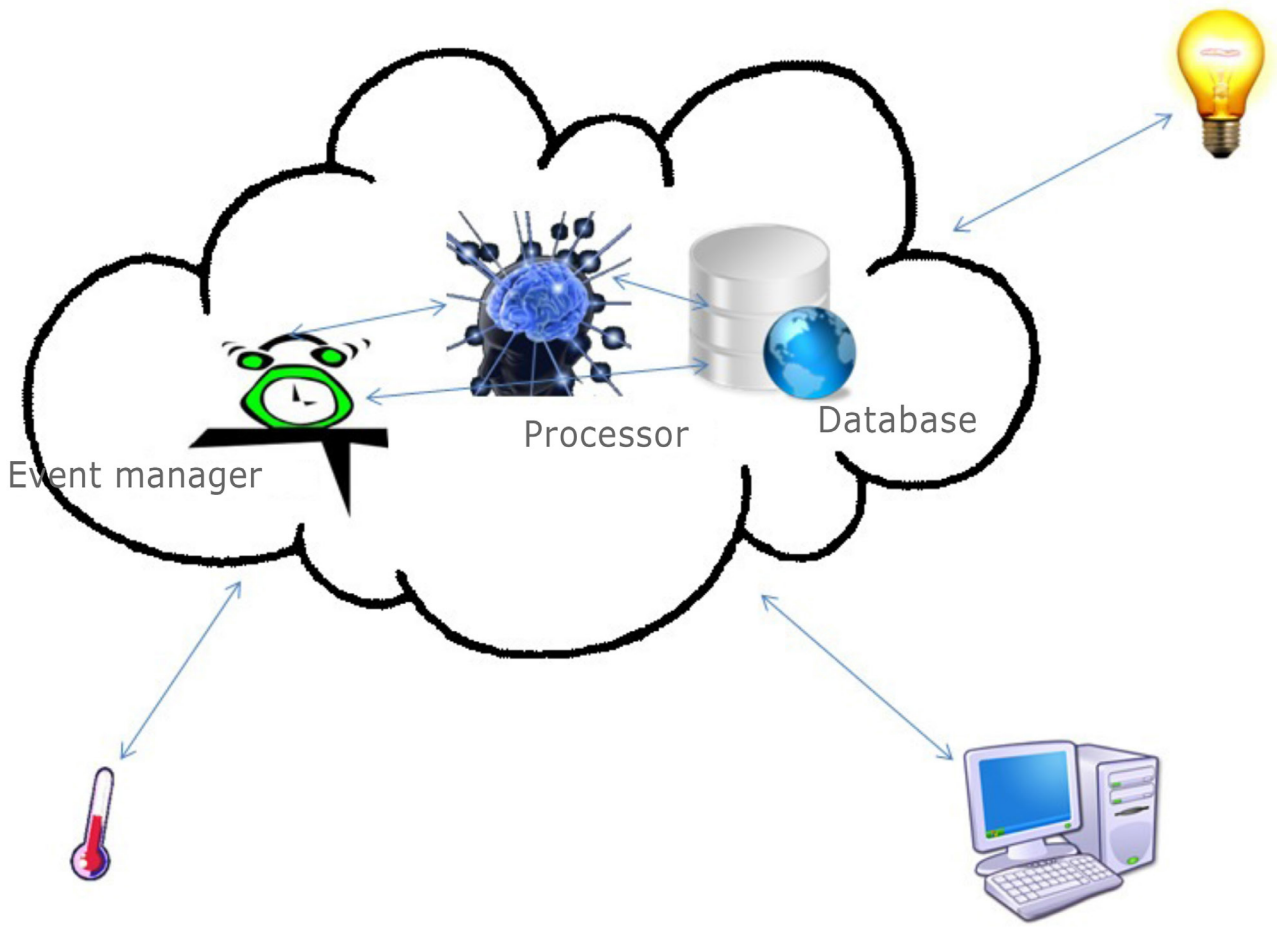


Figure 5. Diagram of the control and communications platform

Bearing the above features in mind, first we developed a **data model** that covers the control and communications platform's data requirements and will serve as a starting point for the design of the platform database.

The different components of the data model have been defined, together with all the physical, logical and descriptive properties that characterise each one and which will serve to store, control and handle the data managed by the platform.

This data model has been defined in accordance with IEEE standard 802.15.4, which specifies the physical layer and media access control for low-rate wireless sensor networks. It is the basis of some of the most wide-ranging specifications in the area of personal area networks and will be the standard on which the control and communications platform will be based. As a result, the vast majority of devices, sensors and actuators that exist on the market can be incorporated into the system.

Furthermore, the **technical and functional requirements and specifications** of the various **business modules** in the control and communications platform have been defined, which includes designing the API (Application Programming Interface) that provides access to the platform's information system platform, i.e. to the database.

In order to **define the business logic**, the API of published services to be used by the various applications has been defined. Thus, the following business modules, which manage each of the logic issues required by the scenarios, have been identified and implemented:

- Sensors / Actuators - Users.
- Sensors / Actuators - Central Control System.
- Central Control System - Web Server.
- Web Server - External Service Providers.

Subsequently, the **interfaces for connecting the data collection and display devices** have been defined. To do so, the technical features in terms of both the hardware and logic required to connect the various components to the system through a generic and open interface have been assessed. Likewise, the communications protocol used to interconnect the different devices (between sensors and the central control system) has been defined, as has **a high-level service API** that enables the information to be managed and structured within a single data model shared by all the devices in the system. The specification will be left open so that further modules that were not initially taken into consideration can be incorporated in the future.

To use the services, first, the requirements of the physical layer necessary for the different devices to make use of such API services have been defined. The use of an "internet of things" concept has been proposed, whereby each of the devices integrated into the system would be able to connect to the Internet via the TCP/IP protocol, thus simplifying the necessary logic and the communication interfaces for the various items.

It is necessary to employ robust information acquisition and management devices to prevent any loss of data, while the possibility of including certain redundancy in the propagation of data packets has also been proposed.

The system should allow three operating modes for the actuators. A manual mode in which the actuators are controlled by the user, an auto mode, in which control of the devices is executed on the basis of the data collected by the sensors and predetermined criteria; and finally a semi-automatic mode, which is a combination of the above and for which pre-requisites will be set by or for the individual user.

Finally, we have defined the **network topology** (bus, ring, etc.) and **connection protocol** (Zigbee, Wi-Fi, Bluetooth, etc.) to be implemented between the data capturing devices and the data displays fitted locally at each site, taking into account the communication requirements in terms of location, mobility, bandwidth, traffic profile, security, etc. Assessment has been made of the possible use of "plug & play" protocols, which minimise the configuration required of any new devices added to the platform.

5. CONCLUSIONS

During the course of the first year **(2012)**, the following results were obtained:

- The needs of the target users - children, the elderly and people with disabilities - have been identified through field research.
- A proposal has been made with regard to a smart home application panel based on those identified needs. These applications provide solutions for the main present or potential obstacles, difficulties or problems as expressed by users themselves.
- The requirements for connecting devices to be integrated into the system have been defined, so that any company that seeks to integrate a device within their product range and intends to use the Platform knows what specifications to follow.
- The specifications of the service API have been determined to enable devices to access the system.
- On the basis of proposals from users, product developments have been prioritised in accordance with their technical feasibility and likely commercial interest such that each IT participant has chosen solutions to be developed during 2013/14 that will subsequently be integrated into the demonstration unit.

6. ACKNOWLEDGEMENTS

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