ICED13
INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED13
19-22 AUGUST 2013, SUNGKYUNKWAN UNIVERSITY, SEOUL, KOREA

A METHODOLOGY FOR INTEROPERABILITY AND INFORMATION MANAGEMENT IN SMART HOME ENVIRONMENTS

Alessandra PAPETTI, Margherita PERUZZINI, Andrea CAPITANELLI, Michele GERMANI
Università Politecnica delle Marche, Italy

ABSTRACT

The environmental impact reduction and the growing world energy demand have generated a strong interest to smart home all over the world. Indeed, thanks to the recent developments in Information and Communication Technologies (ICT) and Internet of Things (IoT), it is possible to create smart home system by making several objects installed at home cooperate each other and offering new services to end users. However, smart home system design is not a trivial task: the increasing embedded intelligence of smart devices is generating a huge quantity of data, which needs to be properly structured and managed, and the related services must be designed and personalized according to the specific users' needs. This paper defines a methodology to support smart home system design and improve smart home information management by selection, aggregation and classification of relevant data, and their correlation to smart home services. The methodology implementation shows how it can support the design of services able to bring benefits to the subjects involved. It also represents the first step towards the creation of a standard by data management and device interoperability for smart home systems' design.

Keywords: information management, device interoperability, smart home system design, service design, product-service systems

Contact:
Dr. Ing. Alessandra Papetti
Università Politecnica delle Marche
Department of Industrial Engineering and Mathematical Sciences
Ancona
60131
Italy
a.papetti@univpm.it

1 INTRODUCTION

The actual growing world energy demand and the high attention to environmental impact reduction are generating a strong convergence of scientific, industrialists and politicians interests towards the use of ICT (Information and Communication Technologies) tools to support a more efficient use of energy resources. In this regard, the concepts of "Smart Grid" and "Internet of Things" push a radical technological change where all objects cooperate with each other, creating a continuous flow of information. This can be used to support real-time decisions, optimize the use of resources and increase the safety and quality of life by providing services. The application scenario can be very extensive; it can interest a big city or a single dwelling. It is worth to notice that actually the residential sector is responsible for about 20% of total consumption and, simultaneously, it is characterized by a lack of citizen's cooperation.

Thanks to the increasing intelligence of smart devices, it is possible to take advantage of the large amount of information available every day about personal actions as well as events taking place at home or outside. However, such huge amount of data often causes inefficiencies and meaningless interpretations if not properly managed. Bad information management and difficulties in capturing and effectively transmitting essential data to become useful information for end-users may drastically reduce the potential benefits and discourage the application of ICT supporting tools. For this purpose, designing a smart home means not only to collect and install several technologies developed separately, but also to provide user-centred services and guarantee the selection and integration of the most appropriate sub-systems able to create an interoperable system architecture. Nowadays, this is still an open issue (Chen et al., 2009). In this context, during the design phase it is essential to support classifying, aggregating and selecting all the information according to the device typology as well as the monitored parameters and the final application and destination.

The paper proposes a methodology to support the design of an innovative information management system able to intelligently manage smart device information in order to make them really interoperable and provide tailored services to final users within the smart home. The proposed approach aims to properly catalogue home devices and information generated by them and define the desired system functionalities able to realize effective information management and device interoperability. Furthermore, it describes how this methodology supports the design of additional services tailored for specific user profiles on the basis of their effective needs. Finally it shows how also the perspective of telemedicine technologies for active ageing and elderly care at home can be exploited by such a system to increase well-being and independence along their entire lifetime and to reduce social costs.

2 BACKGROUND ON ENERGY INFORMATION MANAGEMENT SYSTEMS

Over the years many definitions of smart home have been proposed (Wong et al., 2005). The basic definition defines the smart home as a special home where all the sub-systems are interconnected allowing the homeowner to save energy, to reduce operating costs and to improve safety, comfort and multimedia services. In recent years the technological research leaded to the rapid growth of residential gateways (Perumal et al., 2010) that allows intelligent solutions managing all the devices connected to the home area network (HAN) and integrating different sub-systems.

A considerable amount of new solutions for the smart home automation have been recently developed, i.e. several systems with different communication protocols and architectures. Examples are: Konnex (www.knx.org), Lonworks (www.echelon.com), Zigbee (www.zigbee.org), defined as “open systems”, and SCS by Bticino and Legrand (www.legrand.com, www.bticino.it), Vimar By-Me (www.vimar.it), C-BUS of Schneider Electric (www.schneider-electric.com), defined as “proprietary systems”. As a consequence, a unique and shared smart home standard does not exist yet and tools for the high-level coordination of the smart house, independently from the existing architecture, are still missing.

The availability of common rules is fundamental to make devices produced by different manufacturers interoperable (Kailas et al., 2012) and it is expected that in the future home automation systems will be based on a single standard. However, smart home system design is particularly challenging due to the huge amount of data to be managed and the degree of complexity of the devices’ integration in the home area network.

The introduction of the smart appliances within a home network requires understanding which functions a certain device is able to perform when connected to the network, what information can be

sent and which commands received. The project CHAIN of CECED (European Committee of Domestic Equipment Manufacturers) faced the device interoperability issues and established a preliminary application profile for home connected, which promoted the standard CENELEC (European Committee for Electrotechnical Standardization) in 2007 (EN 50523-1 e EN 50523-2).
Additionally, the design activity is fragmented and focused on single smart technologies neglecting the system overall vision (Perumal et al., 2008). For this reason, it is necessary to define a user-centred design approach that analyzes the users' needs and identifies the services requirements to select the most appropriate system architecture where each sub-system is integrated with the others in order to achieve the customers' satisfaction.
Actually, the majority of projects all around the world are focusing on the energy issue (Alam et al., 2012). The most significant are: Smart Energy 2.0 (USA, www.zigbee.org/SmartEnergy/), Energy@home (Italy, www.energy-home.it), EEBus/E-Energy (Germany, www.eebus.org, www.e-energy.de). They all focus on network energy management through data exchange with smart grids. Therefore, they have the advantage of introducing standard rules for the information exchange between the users and the utilities.
Furthermore, such systems are usually finalized to provide a specific benefit or service such as monitoring, analyzing and estimating the energy consumption (Shin and Hwang, 2012). In this regard, numerous research studies have been conducted about house occupant characterization and behavior modeling, mining and simulation of typical consumption profiles, rule-based management systems for reducing consumptions and feedback interfaces able to persuade users to modify their habits (Bonino et al., 2012). On the other hand, they tend to neglect other types of services that can be connected to the smart home exploiting the same technological infrastructure. Thus, there is a lack of an overall vision and a strategic roadmap for future developments. For this aim, a user-centred design approach is necessary since it supports the design of services able to bring benefits to the subjects involved. Services related to devices remote control have been proposed but there are some open issues regarding their implementation on the white goods (Bansal et al., 2011). Also appliances remote maintenance concept is studied to provide benefits for both users and companies, but it has been considered as a concept independently of any architecture and available tools capabilities (Mullera et al., 2008).
The idea to design and create an integrated system offers also a new way for companies to carry out market analysis and service tailoring, which are still ignored in the majority of manufacturing contexts.

3 RESEARCH APPROACH TO SMART HOME DESIGN

By definition a smart home has a lot of smart devices connected to the HAN, which collect and/or exchange information about some specific aspects. A high-level system design requires a holistic and user-centred approach and must focus on the user's needs satisfaction to support the design of an intelligence-based information management tools. It is a knowledge-based approach; a similar approach have been already adopted in system design, for instance to manage human interactions in extended enterprise (Mengoni et al., 2010) or to benchmark virtual reality tools for specific purposes (Germani et al., 2010; Germani et al., 2009), however it is a novelty in smart home design.
The adopted approach consists of six steps (Figure 1):

1. Identification of the users' needs;
2. Definition of the related service requirements;
3. Classification of smart home devices into a set of homogenous classes (for typology, treated data, home interaction modalities, etc.);
4. Identification of a general information management model characterizing by significant information categories and their correlation with the device classes and specific functioning;
5. Design of the smart home system through the definition of the general architecture able to realize the desired functionalities as well as an effective information management and device interoperability;
6. Design of tailored services to be offered to the users by the involvement of companies and utilities and the definition of a set of application rules, which are executed by an intelligence-based information management tool.

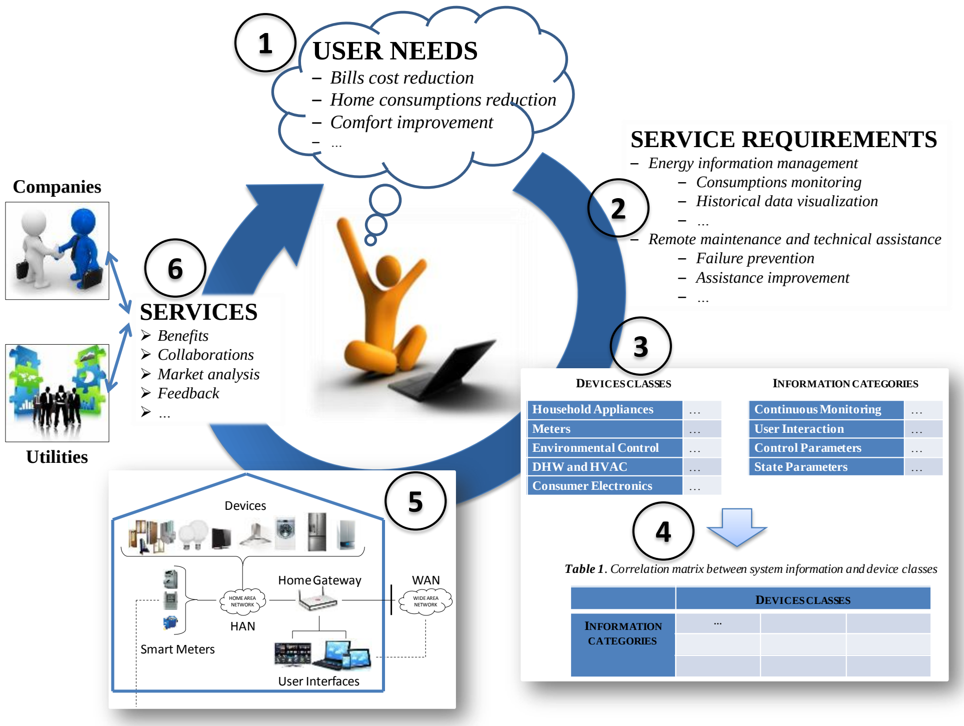

Figure 1. The user-centred design approach for the interoperable smart home

3.1 The smart home device classification and information model

The most common devices in smart homes have been classified into a set of homogeneous classes.

Meters: it includes electricity, gas and water meter, whose data are communicated to the homeowner through the home network and/or to the utilities through the smart grid. Control and safety systems (e.g. electrical safety, gas leaks, water leaks) are included in this category. Thanks to the control parameters it is possible to detect gas or water leak in real time and, consequently, shut off the corresponding meter remotely. Obviously, possible short circuit and electrical overload are monitored.

Consumer electronics: it includes entertainment systems (e.g. TV, game console, audio equipment and players) and small household appliances (e.g. coffee makers, electronic cutters or graters, toasters). They typically have low and constant energy consumption and can be easily switched off/on by a remote control without any preventative measures. For this category the power consumption can be simply monitored as well as its usage (e.g. when and how long they are used; state of devices to allow a remote control).

Household appliances: it includes the major household appliances grouped as cooling (refrigerator and freezer), cooking (oven, hob, hood) and laundry (washer, dryer, dishwasher). Within this category there are some of the most complex devices characterizing a modern house. To be interoperable, they require a microcontroller (Alam et al., 2012), which manages the processes during the automatic operation mode as well as the remote control mode. To be connected to a home network, they need a communication node installed on board or located outside. One example is the so-called "Ultra-Low cost Power-line” (ULP), a cheaper solution (Ricci et al., 2005) developed by Indesit Company, which also contains the Dynamic Demand Control (DDC) technology (Ricci et al., 2008).

Lighting, doors/windows, and security: it comprehends very common components such as lighting, doors, windows, window curtains and shutters. All of them can be control by similar functions, as turn on/off, intensity regulation, opening/closing control, opening regulation. This category also includes the alarm system that considers the intrusion detection sensors for doors and windows. Information is typically used for remote control and interaction analysis. In particular, thanks to motion sensors for automatic light switching, it also possible to localize users and detect an abnormal behavior by recording the user movements. It may be useful for AAL scopes to improve safety and human health.

DHW and HVAC: it includes Domestic Hot Water devices (DHW), Heating, Ventilation and Air Conditioning devices (HVAC), and all the devices and sensors related to their functioning, even when located in different areas or on other devices (e.g. sensors of indoor/outdoor temperature, humidity sensors, etc.).

Such a lot of sensors and devices installed in the home requires managing a large amount of information, understanding their explicit and tacit relationships and identifying logical rules able to support the design of new services or improving the existing ones. To do that information must be properly selected, interpreted and processed. Only in this way, the complexity of the system and the costs can be reduced and the benefits can be higher than the expense. For these purposes, all relevant information has been classified and exploitation rules investigated. In this context several classification criteria are possible, so the proposed cataloguing represents a good way according to the research goals but it cannot be considered exclusive. In the proposed methodology four categories have been defined as follows.

Continuous monitoring: this category includes all the information continuously monitored when the appliances are turned on. Some data are sent to the utilities automatically and are not visible to the user, whereas other data may always be visualized by user interfaces. They mainly consist of resources' consumption data (e.g. energy, water, etc.) and are used for services addressing both the customers and the utilities.

User interaction: it refers to all the information regarding the user-product interaction. Generally, data are aggregated and used for statistics analysis with the final aim to define significant user profiles or frequently events (e.g. wrong actions, selected options, etc.). They are used mainly for marketing analysis and customer care investigations by the producer companies. Data are sent when required.

Control parameters: this category comprises all the data collected to supervise the device or user security, so they mainly refer to the functional device parameters. They are analyzed and compare with the target parameters to predict a hypothetical problem or to detect dangerous conditions. Generally, they are forwarded to companies or service providers when a specific threshold is exceed.

State parameters: it refers to information regarding the device state or a particular stored scenario that are both read when the remote control has to be executed. Such data are used by the system for remote control and device state control.

The system can also consider two extra categories that are not directly linked to the devices, about external and derived data.

External data: it involves all information generated by entities out of the system but integrating all the available data to provide a full overview. External data may concern building and occupant characteristics, economic indicators, fees of utilities, climatic conditions and reference information (e.g., datasheets, standard consumptions, etc.).

Derived data: it refers to all information obtained by data elaboration. Derived data are mainly created for statistics analysis, post-processing, specific service functionalities. Some examples are: average time of use, average expenditure over the time, use frequency of a particular function etc.

Hereinafter, the described information categories are matched with device classes and a correlation matrix is populated with available data (Table 1). For household appliances, since the class is wide and varied, we limit the application scenario to probably the most common device (washing machine) and we classify the information provided by it. However, some data that may be used also for other white goods. Also for DHW and HVAC the class includes numerous devices and systems with different technologies. In this research we refer in particular to hot-water heating and mechanical ventilation system, although the majority of these data are common to all HVAC and DHV systems.

Such a model can be usefully adopted to provide services for customers, manufacturing companies and utilities. The washing machine represents a good example. The customer can monitor the machine consumptions to have feedback on his/her habits and/or product functioning or to verify if an anomaly occurs. At the same time, companies can analyze how users interact with the product and which are their habits (e.g. washing programs or functions are selected more frequently). Thus, it is possible to know if a specific feature has less successful than expected. On the other hand, the users' favourite cycles analysis can support the definition of a new function. In fact, the products are generally optimized according to the standards and the customer habits, but real data can confirm or rebut such preliminary statements. At the same time, technical assistance and customer service departments can analyze cycle execution and verify if the performances are the desired ones by comparing actual data (i.e., control parameters as cycle time and consumption, vibration and noise level, etc.) with threshold parameters. Finally, utilities can read consumption data for each user or user profiles and can optimize the fee or the agreement, also by defining new conditions advantageous for the customers as well as for themselves. Similar information may be considered for the other products of the laundry class. About other household appliances, different data can be monitored but the approach still remains the same. For example for cooking, data will be: cycle, programs and temperature of cooking and the selection of specific functions for the oven; regulation of gas or power intensity for the hob; presence of the cooking smokes; filtering system efficiency; fan speed for the hood, etc. Also energy and security parameters are considered, whereas there are not the state parameters because, for this class, the remote control is not feasible in safety. For fridge and freezer, the characteristic information will be: temperature of the compartments, parameters of the compressor, the evaporator and the condenser and the opening doors to observe also the behavior of an aged person.

Table 1. Correlation matrix between system information and device classes

Devices	**Continuous monitoring**	**User interaction**	**Control parameters**	**State parameters**
Meters	Gas consumption Power consumption Water consumption	Shutting on/off gas Shutting on/off water Shutting on/off power	Electrical overload Short circuit Gas flow rate Gas pressure Water flow rate Water pressure	Electric meter ON/OFF Gas meter ON/OFF Water meter ON/OFF
Consumer electronics	Power consumption	Delay start Turning off time Turning on time	Volume	ON/OFF Standby
Household appliances (washing machine)	Grid frequency Power consumption Water consumption	Delay start Eco wash on Easy iron on Extra rinse on Intensive wash on Pre-wash on Rinse hold on Set program Set spin speed Set temperature Set time to finish Turning on/off time Weight estimation	Cycle time Cycle phases time Detergent level Door lock Drum lock Drum speed Filter occluded Motor efficiency Motor speed Noise level Vibration level Phases consumption Resistance Water level Water conductivity Water pressure Water temperature	ON/OFF Open/Close door Cycle phases in progress Detergent presence Load presence
Lighting	Electricity consumption Ambient light level	Interaction time User in the room Scheduled switch on/off Set light Brightness	Burnt out bulb	Light ON/OFF Light Brightness
Doors/ windows	-	Interaction time Scheduled opening Scheduled closing	-	Open Close Opening rate
Security	Video surveillance	Activation time Deactivation time	Intrusion detected	Alarm system ON/OFF
DHW and HVAC	Room temperature Outdoor temperature Room humidity Power consumption Gas consumption Air flow rates Water temperature for space heating Water temperature (DHW)	Scheduled power on/off Set point temperature Set fun speed Interaction time Set water temperature (for space heating or DHW)	Dirty air Quality of the fume Chimney temperature Chimney draft High/low room humidity High/low room temperature Temperature between rooms Low air flow rates High/low pressures in the pipes Supply/return water temperature in pipes	System ON/OFF Standby

Information regarding other devices such as security, lighting and doors/windows can be useful to increase the people safety and comfort. If a threat is detected, a notification alerts the user through a computer, a smart phone or an audible alarm. The information is also exploited for Ambient Assisted Living (AAL). An example may be represented by the information of the temperature in a home where an elderly person living alone, if the temperature in the home passes a threshold value, a family member or the hospital is immediately alerted. Another example can be done about the energy management of the house. The smart system can push the user towards the best action to reduce consumptions by observing the average temperature of the rooms recorded during the year and how the user has interacted with the devices. This service could be very useful considering that the majority of the energy home consumption is due to space heating/cooling (U.S. Department of Energy, 2011).

3.2 The design of the interoperable smart home

The creation of an interoperable system able to mutually control the devices and properly manage all the data of each device class requires the physical device connection to the HAN and the communication infrastructure to deliver all the collected data and make them available to other systems (e.g. for data analysis, for user monitoring, for remote control).

The physical device connection can be implemented in various ways as each device has different capabilities in terms of distance, speed and volume data transfer. The list below shows the physical media used in the smart home.

Power line: it consists of the existing house wiring that supplies all the electrical devices and exploits the principle of the Power Line Communication (PLC) technology. Since every home already has it, the power line is convenient and does not require any additional wiring (Usman and Shami, 2013). Communication standards for power line are X10 (www.x10.org), HomePlug (www.homeplug.org) and LonWorks (www.echelon.com).

Phone line and other wiring: it includes all the other wirings of the smart home, such as twisted pair, coaxial cable, fiber optic and others. They allow managing wide bandwidth data, as required by the entertainment system, the computer, etc. Some wired communication standards are Ethernet, USB (www.usb.org), HomePNA (www.homepna.org).

Wireless: it is a network using electromagnetic waves to connect the devices and send/received information. It is practical because it allows connecting numerous devices in an easy way and also including devices not connectable by a physical cable. Well-known wireless communication standards are ZigBee (www.zigbee.org), Wi-Fi (www.wi-fi.org), Bluetooth (www.bluetooth.com).

It is worth to consider that each device has different requirements in terms of connections and communication protocols and a residential gateway is required. Such an object represents the link between each device connected to the HAN and is able to manage traffic information. It also serves as a bridge between the local network and the external one (internet) and allows connecting the HAN with other management systems (Cheng et al., 2012). The gateway allows the proposed tool to leaning on the existing architecture. Such a tool supports the identification of the most appropriate technologies to be installed in order to satisfy the user needs. The user (e.g. homeowner) can interact with the system directly by a Graphical User Interfaces (GUI) or indirectly via computer and/or smartphone. The latter works both locally and remotely. Therefore, the user can monitor home conditions, control the devices and be informed about specific data (e.g. device consumptions). Even utilities and companies can access some data transmitted from the smart home, according to the privacy policy, for supporting some specific services (e.g. remote technical assistance). Figure 1 shows the proposed system architecture.

4 SMART HOME SERVICE DESIGN

This section presents how the proposed approach can be adopted to provide consumer services by managing the information within an interoperable smart home environment. Proposed services are grouped in significant typologies and described. The tool rationale is shown for the remote maintenance service to demonstrate the method application at the operative level. Finally, the achievable benefits can validate the methodology proposed. The benefits could be demonstrated also by usability and sustainability analyses.

4.1 Remote maintenance and technical assistance service

For this service the "Control parameters" information category is considered to evolve the concept of maintenance by directly interacting with devices at work. In fact, corrective maintenance can be replaced by a more accurate preventive and predictive approach. For instance, companies and users can obtain mutual benefits: companies can monitor specified parameters to prevent a failure and observe the appliance behavior to improve the product itself; contemporarily customers can have a continuous assistance, a reduction of product failure and downtime and finally a lower global consumption. Furthermore, users may receive real time indications if their product care is not appropriate. Contrariwise, currently users may not observe a malfunctioning for a long time while the product consumptions increase. An example of tool rationale related to the washing machine remote maintenance is shown in Figure 2. A similar overview could be provided also for the other services.

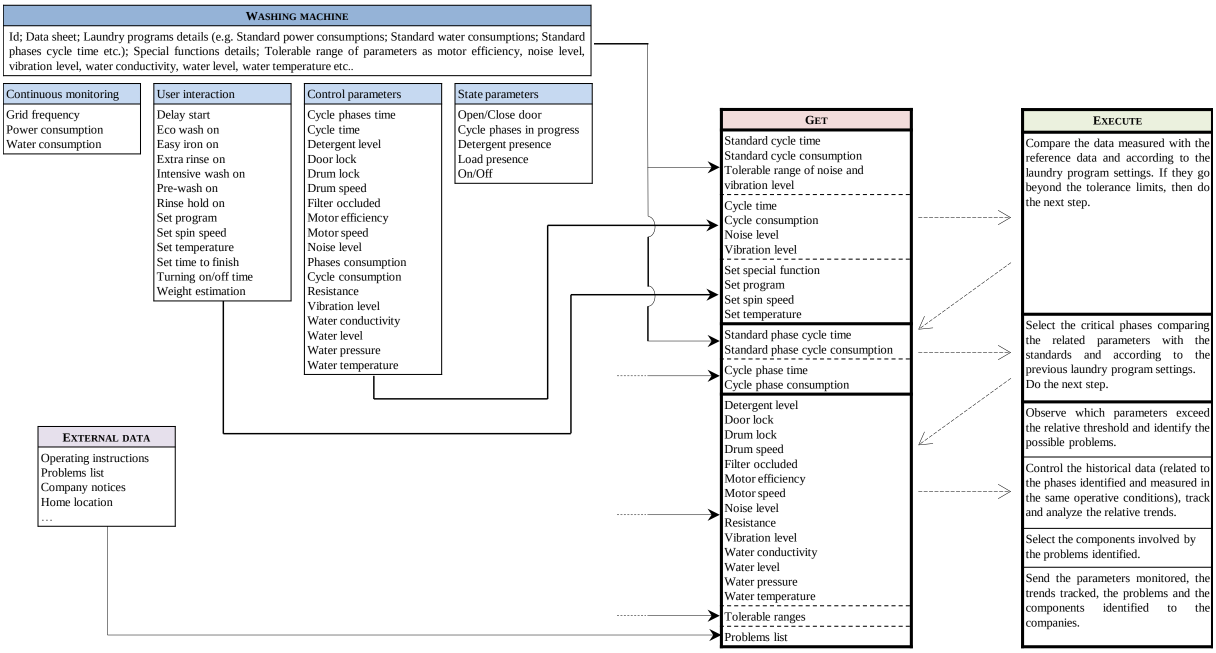

Figure 2. Tool rationale related to the remote maintenance service

4.2 Energy information management service

This service aims to support numerous smart home functionalities about real time monitoring of energy consumption. Such information is provided by appliances through the embedded intelligence or smart plugs, and sent to the gateway via the HAN. Data collected (e.g. consumed energy, actual fee, user expenditure) can be shown to customers in several ways (Internet, smartphones, display, reports, etc.) and presented in different formats (e.g. tables, graphics, etc.). The main beneficiaries are final users, who can monitor their energy habits, compare their consumption with set goals and know how improve their behavior, view statistics about total consumption or aggregate data for device category or a certain period of time, analyze historical trends in consumption, and see how home consumption evolves over time. A specified application may be developed to show to customer the most proper energy fee policy according to their energy use. Available data can be also used to forecast the future consumption and provide indications to users. Results from research studies show that direct power feedback provided by this kind of system encourages people to make more efficient use of energy (Bonino et al., 2012). The proposed approach is not limited to electricity, but it can handle other resources such as water and gas. Thus, user can also know if there are leaks in real time. Information can be also dispatched to utilities via smart meters to allow optimizing the resources management and equilibrating the electric network thanks to DDC technology (Ricci et al., 2008).

4.3 Market exploration and statistical analysis

Information related to the "User interaction" category can be exploited by both manufacturing companies and service providers to define some user profiles and design personalized services according to their needs. In fact, being aware of how the users interact with the appliances is essential to improve and customize products and offer more satisfying services. Indeed, standard market analysis can not always provide truthful and accurate data because they strongly depend on sample users' collaboration and personal subjectivity. In this case, statistics will be based on daily behavior observation and direct analysis of the interaction between users and products. This information joined whit "External data" can characterize also a certain geographic area. It can improve the company strategies by low cost investments.

4.4 Device remote control service

The proposed system also facilitates the implementation of device remote control, which is a crucial aspect to guarantee people safety and comfort. Up to now, domotic systems offer to regulate lighting, heating, security systems and entertainment electronics, but their implementation is not very widespread yet due to the absence of a unique control system, the necessity of multiple user interfaces, and the complexity of the overall architecture. Contemporarily, the remote control of household appliances is still too complicated since products intelligence and standards costs are too high. The proposed approach can provide a common ground to connect all devices supporting the smart home design phase and the existing technologies selection according to the different purposes. In this case, the Power Modulation can represent a first solution forward controlling any device inside the house. The "State parameters" information is the basis to realize such a service.

4.5 Ambient Assisted Living services

The elderly population is rapidly increasing; this fact pushes to take advantage of available technologies to improve their wellbeing and support a correct lifestyle. Numerous home automation systems have been proposed and lots of smart objects have been designed with the aim to communicate important information for elderly assistance. However, there are strong barriers to their implementation mainly due to the information management issues and the lack of high-level overall system design. In this context the proposed approach can represent the first precondition for their diffusion: necessary data can be derived from direct observation of interaction between the elderly and the appliances and such information can be collected without additional costs. Data can be used to monitor user’s habits or to remotely control some devices that, for example, could be too difficult to activate for an elderly. The approach is similar to previous cases. This service finally allows investigating how aged people live daily and capture alarming signals to make them live safe. Thus, elderly can feel more independent and improve their quality of life. In the same time, they are monitored continuously and relatives are advised immediately if they need help. Such a service can be enhanced by identifying possible health issues or preventing dangerous situations thanks to dedicated post-processing applications.

4.6 Benefits of service innovation

The service described in the previous paragraph can offer benefits to several subjects: consumers, utilities, manufacturing companies as well as governments and public entities. Consumers have the possibility to save money and improve the quality of life since they worry no more about product assistance, they have home consumptions monitored and constantly verified, and they are safer without any change to their lifestyle. Lots of customized applications can be developed to incline people towards smart homes and solutions of the future. Furthermore, customers can agree with the companies to provide a specific service: for instance, they could have free assistance in exchange of continuous feedback. In this way, industries can have direct and reliable product and service evaluations without additional costs. Furthermore, both consumers and companies can choose which data to be monitored, how to be informed and when to receive information according to their own purposes. About utilities (e.g. energy, water, etc.), they can improve their current advantage from smart meters by a better management of the entire network. Thanks to the proposed approach, the electrical utilities can also benefit from the integrated DDC technology, and nor companies nor users have to pay for it. Utilities can also encourage this solution rewarding users by free electrical supply or cost reduction. Finally, governments and public entities can benefit from Ambient Assisted Living services, which improve elderly people wellbeing, limit their stay in medical centres, and reduce social costs in general. Obviously, also the environment takes advantages from the reduction of the resources’ consumption.

5 CONCLUSIONS

This paper presents a methodology to support smart home system design and improve information management in order to promote the creation of a new standard for smart device interoperability. It allows classifying data originated by different appliances and matching them with an information management model to finally propose an intelligence-based service tailoring. In this way, information can be easier extract, elaborated and exploited according to the users’ needs and the service requirements identified. For each device class, the basic information to be managed are identified and associated to a system category. Such correlation represents the first step to create a standard for information management promoting system interoperability. The method addresses a domestic environment, but it could be translated also in similar contexts.

The paper presents how the methodology supports service design by adopting a user-centred approach. It describes several services such as energy saving, remote maintenance, devices remote control, assisted living. Future works will consider a more detailed information asset for each device class and a wider classification by considering all the devices that can be installed at home, as well as will implement a smart home system prototype, test the planned functionalities and evaluate the service performances by usability and sustainability analyses.

REFERENCES

Alam, M. R., Reaz, M. B. I. and Ali, M. A. M. (2012) A Review of Smart Homes-Past, Present, and Future. *IEEE Transactions on Systems, Man, and Cybernetics-Part C: Applications and Reviews*, Vol. 42, No. 6, pp. 1190-1203.

Bansal, P., Vineyard, E. and Abdelaziz, O. (2011) Advances in household appliances - A review. *Applied Thermal Engineering*, Vol. 31, No. 17-18, pp. 3748-3760.

Bonino, D., Corno, F. and De Russis, L. (2012) Home energy consumption feedback: A user survey. *Energy and Buildings*, Vol. 47, pp. 383-393.

Chen, C.Y., Tsou, Y.P., Liao, S.C. and Lin, C.T. (2009) Implementing the Design of Smart Home and Achieving Energy Conservation. *7th IEEE International Conference on Industrial Informatics, INDIN 2009*, pp. 273-276.

Cheng, S. T., Wang, C. H. and Horng, G. J. (2012) OSGi-based smart home architecture for heterogeneous network. *Expert Systems with Applications*, Vol. 39, No. 16, pp. 12418-12429.

Germani, M., Mengoni, M. and Peruzzini, M. (2010). A benchmarking method to investigate co-design virtual environments for enhancing industrial collaboration. *ASME World Conference on Innovative VR 2010*.

Germani, M., Mengoni, M., Peruzzini, M. (2009). Metrics-based Approach for VR Technology Evaluation in Styling Product Design. *ASME 2009 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (DETC/CIE)*, Vol. 5.

Kailas, A., Cecchi, V. and Mukherjee, A. (2012) A Survey of Communications and Networking Technologies for Energy Management in Buildings and Home Automation. *Hindawi Publishing Corporation Journal of Computer Networks and Communications*, Vol. 2012, pp. 12, 932181.

Mengoni, M., Germani, M., Peruzzini, M., Mandolini, M. (2010). A novel knowledge-based approach to support virtual teamwork in collaborative design. *Virtual Engineering, International Conference on Tools and Methods of Competitive Engineering TMCE 2010*, Vol. 1, pp: 461-474.

Mullera, A., Marquezb, A. C. and Iung, B. (2008) On the concept of e-maintenance: Review and current research. *Reliability Engineering and System Safety*, Vol. 93, No. 8, pp. 1165-1187.

Perumal, T., Ramli, A. R., Leong, C. Y., Mansor, S. and Samsudin, K. (2008) Interoperability for Smart Home Environment Using Web Services. *International Journal of Smart Home*, Vol. 2, No. 4.

Perumal, T., Ramli, A. R., Leong, C. Y., Samsudin, K. and Mansor, S. (2010) Interoperability Among Heterogeneous Systems in Smart Home Environment. *Atlantis Ambient and Pervasive Intelligence*, Vol. 2, pp. 141-157.

Ricci, A., Aisa, V., Cascio, V., Matrella, G. and Ciampolini P. (2005) Connecting electrical appliances to a Home Network using low-cost Power-Line Communication. *International Symposium on Power Line Communications and Its Applications*, pp. 300-304.

Ricci, A., Vinerba, B., Smargiassi, E., De Munari, I., Aisa, V. and Ciampolini, P. (2008) Power-Grid Load Balancing by Using Smart Home Appliances. *Digest of Technical Papers. International Conference on Consumer Electronics, ICCE 2008*, pp. 1-2.

Shin, J. and Hwang, J. (2012) Intelligent energy information service based on a multi-home environment. *Procedia Computer Science*, Vol. 10, pp. 197-204.

U.S. Department of Energy, (2011) Buildings Energy Data Book, http://buildingsdatabook.eren.doe.gov/ChapterIntro2.aspx.

Usman, A. and Shami S. H. (2013) Evolution of Communication Technologies for Smart Grid applications. *Renewable and Sustainable Energy Reviews*, Vol. 19, pp. 191-199.

Wong, J. K. W., Li, H. and Wang, S. W. (2005) Intelligent building research: a review. *Automation in Construction*, Vol. 14, No. 1, pp. 143-159.