VALUE CO-CREATION IN A VIRTUAL SMART BUILDING SERVICE ENTERPRISE FOR ENERGY EFFICIENCY AND ECONOMIC SUSTAINABILITY

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Abstract

Today, a new generation of software applications can be developed, as IT services developed by software providers can be integrated by solution developers in complex control and monitoring Smart Building Management solutions. This paper introduces the concept of Virtual Smart Building Service Enterprise (SBSE) as a novel perspective to develop an innovated services ecosystem for smart buildings. The Virtual SBSE allows different stakeholder categories to interact in order to develop, publish, compose, discover, integrate and use specific functionalities exposed as services for smart building management. An extended implementation case study is developed around an open software platform for modelling, virtualising, and managing complex services, including energy consumption. It integrates in the operational loop a Smart Building Controller exposed as a service that home users can download, install and use in their homes for the control and monitoring of energy consumption, or for ambient comfort. Different schedules and policies for individual devices or groups of devices can be defined based on daily working or living user schedules, so that the users may evaluate and adjust energy cost based on their own preferences, achieving their energy efficiency goals. The Virtual SBSE concept and the energy efficiency case study presented in the paper demonstrate how the easy open integration of diverse information systems enabling the creation of new smart building management services and involving users in value co-creation can be attained.

Keywords: energy efficiency, smart building, smart building management, value co-creation

1. Introduction

Intelligent Building Management is a term that defines today a broad set of approaches, technologies, methods, tools, and devices that crystallize an increasing awareness towards environmental and safety issues (Hensen and Augenbroe, 2004; Patrascu and Dragoicea, 2014;
Alexander, 2002). It can be approached on different levels, through legislation, local initiatives of citizens, and businesses organizations to better insulate and to install renewable energy sources, but also through better monitoring and control of building energy and safety performance (EC, 2009). In this respect, the ICT sector can deliver tools that are vitally needed to collect, process and manage pertinent data, and to present them in a standardised format, in order to facilitate policy implementation and effective measuring.

Today, the integration of different ICT technologies and solutions can assign new functions to a specific Intelligent Building Management solution. It is a well known fact that the increasing number of networked home appliances and devices, coupled with the widespread availability of broadband communications, is enabling new “intelligent” building automation functionalities, not only for energy management (Wilby et al., 2014) but also for safety and security, for example, intelligent control for seismic risk reduction (Patrascu, 2011; Marmureanu et al., 2013), health and wellness (Thuemmler et al., 2012), or Intelligent Operations Centres for Smarter Cities (IBM, 2013a).

We are also talking about a natural tendency to distribute system functionalities over the ubiquitous computing devices inside and outside the building environment, providing that information appliances with computing capabilities are ubiquitous (Wu et al., 2007; EC, 2010). In this respect, we speak now in terms of smart (IBM, 2013b), as a growing number of Smart Building Management projects are initiated around the world and address various aspects of building monitoring and control.

In a Smart Building Management solution, intelligence is based on centralized control through a home server or gateway. Home Automation (Bucur et al., 2011), Smart Home (SmartLabs, 2013), Smart Energy (SmartEnergy, 2013) are only a few names to define the current designs of Smart Building Management perspectives that allow real time monitoring and data collection across different infrastructure components, centralization of real time events and data building in order to enable infrastructure-wide analytical and optimisation capabilities (Dragoicea et al., 2012).

At the same time, Smart Building (IBM, 2012) is a new paradigm to deliver Intelligent Building Management solutions that offer opportunities for innovative services built on the computational power and scalability of the Internet. It has the power to collect consumer knowledge through smart devices that can be aggregated and stored to provide insights about consumer needs and behaviour. In a smart building, energy, lighting, fire, monitoring, water, access and security systems, as well as seismic risk monitoring, can be designed to run more efficiently and, more importantly, to communicate with one another. This would deliver consumer benefits that have never been considered before and would radically improve the performance of current devices and
services delivered through smarter components for everyday activities: *smart transportation, smart cities, smart education, smart energy* (IBM, 2013b), to name but a few.

Therefore, in a Smarter City (IBM, 2013a), a *Smart Building* can be represented as a *system of systems* within a larger ecosystem (Dragoicescu et al., 2013; Patrascu and Dragoicea, 2014).

In this respect, a new generation of intelligent building applications shift from the centralized, local desktop applications toward the provisioning of distributed geo-spatial services and components, focusing on inter-operability of functionalities exposed as services (Atzori et al., 2010).

State-of-the-art perspective on available *Smart Building Management* solutions reveals three specific R&D directions. The first one refers to the development of mobile, embedded, SOA and Web-based distributed computing solutions to deliver improved value for customers with smart home appliances (Tsai et al., 2011; Wu et al., 2007; Ricquebourg et al., 2006).

Most of these developments tried to build robust and reliable systems that could offer comfort, while reducing operational costs of the building and fulfilling user demands. The SOFIA project (Katasonov and Palviainen, 2010) created its own version of a smart home. The Hydra project (Hydra, 2010) proposed a service-oriented network to support smart home applications. Siemens Smart Home Solution (Siemens, 2008) is based on cellular phones and addresses comfort, security, energy (HVAC and lighting), healthcare, communication, and entertainment. The eDIANA project (eDiana, 2011) addresses energy efficiency using an embedded technology. The E3Soho project (e3Soho, 2013) implements a feedback loop on consumption and personalized advices for improving energy efficiency. The Wink (Wink, 2015) initiative (including General Electric, Honeywell, Philips, and Rachio) proposed a smart home solution based on a proprietary hub communicating through Wi-Fi, Bluetooth, Z-Wave, and ZigBee, and being able to adapt to a wide range of product types. SmartThings (SmartThings, 2015) is an open platform for smart home devices that supports more than 1,000 devices and 8,000 applications. All these projects involve different technologies, they have different focus and objectives: a tiered architecture and a service-oriented approach for facility management (Hydra, 2010), computing processors to support smart home applications (Wink, 2015; SmartThings, 2015), leveraging a large pool of devices and know-how to support a wide range of home activities (Siemens, 2008; Wink, 2015).

The second R&D approach refers to the development of *modelling and simulation tools* to analyse, monitor and visualize design and operation of buildings from different perspectives (Beguery et al., 2011; McGlinn et al., 2010; Van Nguyen et al., 2009), to assess variants of environmental performance of buildings (Hensen and Augenbroe, 2004), to dynamically evaluate buildings at run-time (Loonen et al., 2010), to optimise design (e.g. by testing alternate design solutions, changing materials, developing distinct scenarios, etc.) through energy efficiency analysis.
and simulation services (Dragoicea et al., 2013). Today, novel *modelling* and *simulation* techniques reveal a completely new perspective on designing and evaluating *Smart Building Management* solutions (Dragoicea et al., 2012; Patrascu and Dragoicea, 2014), aiming to sustain structural integrity, consistently ensuring structural safety and disaster risk reduction, in relation to assessment and planning, pre-impact preparation and emergency and restoration activities (Alexander, 2002).

A third research perspective that has recently emerged defines the “building system” concept, where the building “product” itself is seen as a support for service provisioning and improvement (Mauger et al., 2013). Here, the requirements definition of buildings’ conceptual phase does not focus on the building structure itself, but on the services it can provide to the specific customers (stakeholders). Therefore, the building construction not only shelters human activities, but it can be evaluated also against its major impact on the services provided to the community. The “smart building”, as a system of systems in a larger ecosystem, delivers services for the stakeholders as a result of interactions with other products and services within that ecosystem (Patrascu and Dragoicea, 2014). This needs collaboration and information sharing. In a smart building, system functionalities are distributed over the various intelligent, interconnected, instrumented devices in the building environment. The smart building system should interact with other systems external to the building itself. Therefore, a natural integration with the concept of Smarter Cities arises (Allwinkle and Cruickshank, 2011), as Smarter Cities are regarded as the European Agenda that involves an integrated and intelligent vision for growth of urban areas (Vlasák, 2010; Cavalieri, 2013).

The research perspective presented in this work proposes a novel user-centric approach towards the development of *Smart Building Management* solutions that would allow users to interact on-line with a smart building service ecosystem. A *Virtual Smart Building Service Enterprise* (Virtual SBSE) able to sustain this service ecosystem is defined, and aspects of value co-creation between stakeholders are highlighted. The role of the platform in service innovation, service composition and delivery is emphasised along with a case study for energy efficiency. The introduction of the Virtual SBSE highlights the importance of integration of existing business functions with new applications according to the service-oriented architecture approach as a mean to facilitate agility, cost reduction, reusability and rapid implementation of new business functions. From a service provider point of view, the main focus shifts from efficiently providing new software solutions that support smart building services to suitable adaptation of their software systems (in terms of architecture) to combine technology with innovative business models to better respond to customers. From a service consumer point of view, applying foundational principles of the new science of service (Maglio and Spohrer, 2008) to design value co-creation interactions
supports developing empowered service consumer experiences embedded in an innovative smart building service ecosystem.

The paper is organized as follows. Section 2 introduces the concept of Virtual Smart Building Service Enterprise that allows approaching different types of services for smart building management, related to comfort and safety or emergency management. Section 3 exemplifies how the concept of the Virtual SBSE is used in order to build a complex technology-driven service ecosystem where different aspects of value co-creation between various stakeholders can be highlighted. Two examples of utilization are presented, being developed along with an open software platform, and they are related to the development of special modelling and simulation services and control and monitoring services. Section 4 presents discussions on the proposed working method, while section 5 concludes the paper with some final remarks and a further development perspective related to open development of complex value propositions in the Virtual SBSE perspective.

2. Virtual Smart Building Service Enterprise

Today, a smart building integrates a whole range of smart devices, being designed to run more efficiently and to communicate with and about its various sub-systems assuring the interoperability of basic functionalities as services (Dragoicea et al., 2013). In this respect, different types of services can address needs on different levels, related to comfort and safety (e.g. home owners get remote access to their homes or office locations to set up environment conditions based on their daily schedule, preferences, and energy efficiency) or to emergency management (e.g. services developed to connect the control and monitoring building sub-systems with emergency units that can have access to important information regarding the building in case of a disaster).

In this respect, a complex smart building services ecosystem can be suggested. These services can be broadly classified as:

- services for ambient monitoring and control: e.g. remote access to room temperature and ambient light control; access to adjust office conditions based on a predefined working schedule;
- information services: e.g. obtaining information about building status on mobile devices or through an Internet access point; visualization of building data available to the building manager;
- services to support emergency intervention: e.g. integration with the seismology networks to provide early warning in case of natural hazards such as earthquakes (Niep, 2013); alerts in case of fire detection; automatically remote switch off of utilities (gas, electricity and water)
in case of emergency; triggering of emergency procedures, like emergency lights, for human protection; automatic control of elevators to rest at the ground floor;

• services to support energy efficiency: e.g. smart grids;
• services to support construction safety: e.g. evaluation of earthquake risk for old buildings, creation of earthquake risk maps in big cities.

This perspective imposes to automate the current processes, for example to call emergency services and cut off utilities to improve the existing emergency scenarios. The smart building can be therefore connected to a city central management unit (an IOC – Intelligent Operations Centre) having an overview of an entire city and being able to provide valuable information.

This gives the opportunity to co-create value between the smart building service customers (e.g. home owners, building managers, utilities providers) and the smart building service providers (e.g. software developers, application integrators that develop smart building management solutions) by adapting each service to the customer’s needs and creating the possibility to get real-time feedback from the service customer. Therewith, the service provider can implement new ways of applying the service offerings by analysing user behaviour in different situations (e.g. emergency situations).

In this respect, user-centricity is a concept that is applied more and more to develop a new generation of services highlighting customer input that distinguish service processes from non-service processes (Sampson and Froehle, 2006). A service has special characteristics, like intangibility, inseparability, perishability and simultaneity (Sampson and Froehle, 2006; Sampson, 2010), and this requires a special approach to organize service system activities in order to customize services based on consumer’s requirements.

The development of new capabilities for smart building management is approached here around the notion of service, i.e. the result of the application of specialized competences through deeds, processes, and performances towards an identified need to benefit another (Vargo and Lusch, 2004), by defining a Virtual Smart Building Service Enterprise (Fig. 1). The Virtual SBSE is located in the centre of the service triangle (Grady, 2002) such as complex service interactions can be formed and explained.

The Virtual SBSE is able to integrate information from multiple sources to deliver consistent, timely and meaningful data to support its business processes. It virtualizes diverse sources of information to provide a unified business view over the smart building operation processes. Information is collected, processed, analysed and transformed to meaningful data through automation, supporting better decision making processes at different levels. The Virtual SBSE is characterized internally by an extended connectivity among its components’ configurations
and interdependencies, and externally through its stakeholder interactions in a value co-creation network.

Consequently, a large set of stakeholders benefiting from this sort of approach can be identified, such as:

1. Software service providers: They are software developers that develop and publish IT services that can be discovered by the application integrators that develop services in the context of the *Smart Building Management* concept;

2. Cloud providers: They host the entire informational infrastructure that provide access to the different building subsystems, through the *Smart Building Management* solution;

3. Building administrators: They get a real-time overview of the entire building to better manage different operational aspects like power consumption, comfort levels, etc.;

4. Home owners: People who live or work inside the building getting remote access to their homes and offices;

5. Emergency units: They have an easier access to the locations inside the building, without interfering with the management of utilities during their interventions;

6. Constructors: They use building related data acquired through smart sensors for future developments;

7. Household goods manufacturers: This category of stakeholders refers to manufacturing units that produce different kinds of home appliances and devices;
8. City halls and seismology institutions: They use data to develop intervention procedures in case of emergencies;

9. Smart community: New service business models in European cities should prove their economic sustainability through the empowerment of their citizens who can actively evaluate and become aware of sustainable resource consumption;

10. Smart government: A modern city involves many actors, like local communities, authorities, non-governmental organizations, agencies, integrating people, resources, technology and organizations that provide services. It is a complex socio-technical system and its social and economic evolution cannot be evaluated, analyzed, and governed by disjointing the behaviour of its subsystems (buildings, energy, transport, healthcare, education, security, food, commerce, etc.). Therefore, the role of the Virtual SBSE concept is more strongly emphasised along with the service relation formation and interaction evaluation in the urban dynamics context, through service composition.

The Virtual Smart Building Service Enterprise can be characterized as a service system that integrates different types of resources:

- Technology: refers to the internal network that connects all different types of sensors or actuators, (e.g.: alarms, heating and cooling devices, access doors, elevators and water dispensers) and the external communication network (connection with the cloud provider, where the management software can be hosted, with the emergency units, seismology institutions and other authority institutions);

- People: the people that live or work inside the building, e.g.: home owners, security officers, building managers, emergency crews, etc;

- Knowledge: for each stakeholder, as mentioned before, information is gathered for further analysis, decision making processes are executed and defined, intervention and operation protocols are implemented;

- Conceptual resources: the software platform used to control and monitor the smart building, and policies, schedules, access rules and emergency plans that are to be conducted. These conceptual resources reside in the service provider’s information system;

Access to the smart building resources based on the above mentioned types of services is granted based on access rights:

- Privileged access: resource available only for the building manager who can override the rights and commands of every usual user;

- Owned: access to the devices for monitoring, sensors, interconnecting network of all pieces of smart equipment, policies implemented for energy saving and hazard behaviour of the building;
• Shared access: access to the central management system and the portal, hosted by a cloud provider; can be accessed by multiple entities, such as building managers, security officers, people that work or live in the building.
• Existing services based on service consumer feedback and preferences.

3. Implementation examples

This section exemplifies how the concept of the Virtual SBSE introduced in section 2 can be used in order to build a services ecosystem for smart building management. For demonstration purposes, an existing open platform (Fcint, 2014) is used as a test bed (Fig. 2).

This platform is intended to allow different stakeholders to participate and contribute at developing, maintaining and exploiting smart building management solutions. In this way, both users and developers can compose new services, while the developer can focus on the most effective use of devices and data, instead of getting lost in upgrading to the latest device driver. The FCINT platform proposes a service-oriented approach to control and manage building facilities via intelligent controllers in a SOA framework (Chera and Petrescu, 2013). In this way, the software platform supports both information integration from different sources and service publication, discovery and integration in a service oriented perspective (Tsai et al., 2011).

![Virtual SBSE](image)

**Fig. 2.** Virtual SBSE integration with different stakeholders, adapted from (Fcint SBC, 2014)
From the smart home user perspective, the main use cases can be summarized as follows:

- a home user uses the Smart Building Controller for simulation purposes: a Smart Building Controller is integrated in a simulation loop in order to control real and virtual devices at the facility level. The simulation models based on real and virtual devices are integrated in a building model in order to test the functionality of intelligent building control components (like smart building controllers), and to estimate and evaluate power consumption at the facility level. This use case is described in section 3.1;

- a home user uses the Smart Building Controller service in his smart home: he downloads the Smart Building Controller from the FCINT portal and installs it inside his smart home; he discovers device web services for his own devices on the FCINT portal and installs them; he creates the connections between devices and the related web services, then devices are discovered and installed into the SBC; he defines a number of schedules for individual devices or for groups of devices, which are ready on the SBC for execution; he defines a number of policies for individual devices or for groups of devices, which are ready on the SBC for execution; he can supervise and control the system from the building’s LAN or from the Web. This use case is described in section 3.2.

3.1 Modelling and simulation services

A proposal on developing a novel modelling and simulation technique for the evaluation of Smart Building Management solutions was introduced in (Dragoisea et al., 2013). It is based on the FCINT service oriented modelling and simulation architecture. Different use cases were defined regarding the usability of the proposed open platform (Fig. 3).

The novelty of the proposed framework consists of the integration in the simulation loop of a Smart Building Controller able to control real and virtual devices at facility level. The web-based service oriented software application allows simulating the device-level and facility level behaviour of different components and sub-systems in a smart building. It demonstrates a strategy to define a Smart Building Management solution that includes scenario simulation, testing the functionality of the Smart Building Controller (SBC), device monitoring and control, report generation, and implementation of device web services.
In the perspective of the Simulation Framework proposed in (Dragoicea et al., 2013), the following definitions of schedules and policies are introduced.

**Definition 1.** A *policy* represents a set of rules of the form:

\[
\begin{align*}
\text{ON} & \ (\text{Trigger}) \ \text{IF} \ (\text{Condition}) \ \text{THEN} \ (\text{Execute block of actions 1}) \\
\text{ELSE} & \ (\text{Execute block of actions 2})
\end{align*}
\]

where:

- **Trigger** specifies the name of the rule trigger. It can be set to true or it can take the name of an event type registered in the SBC, such as *PresenceOffice*;
- **Condition** is an expression recognized by the SBC at runtime and evaluated as a boolean value.

**Definition 2.** A *schedule* is a parseable and executable instruction set for the control of physical devices and device groups in a Smart Building Controller, where actions are associated with certain days of the week or particular date intervals of the year and certain hour:minute pairs.

A schedule is organized into data structures of the form: \{*From*, *To*, *Schedule ID*, *Schedule Name*, *AppliesTo*, *WeeklySchedule*, *ExceptionSchedule*\}, where:

- **From** and **To** are calendar dates between which this schedule is applied;
- **Schedule ID** and **Schedule Name** uniquely identify the schedule in the system;
- **AppliesTo** identifies the device to which the schedule is applied;
• **WeeklySchedule** is a set: {((Monday, list of actions), (Tuesday, list of actions)) ... (Sunday, list of actions)};

• **ExceptionSchedule** is a set of one or more date intervals that override the WeeklySchedule: {((startDate,endDate), list of actions) ... ((startDate,endDate), list of actions)}, where (startDate,endDate) specify particular calendar date intervals that, together with an associated action list, make up the exception schedule.

Based on a schedule, the Smart Building Controller executes a set of operations assigned to dates and times, by executing commands to their control drivers that are exposed as web services. A schedule is evaluated periodically by the Smart Building Controller and all device or group control commands are parsed and executed once every minute.

Previous work in this direction is related to the definition of the way in which emergency response protocols can be combined at a microscopic level with a Smart Building Controller so that a high level of performance in what concerns comfort could be assured (Dragoicea et al., 2012).

The case study (CS1) presented in (Dragoicea et al., 2013) defined a testing scenario for the Smart Building Controller in emergency situations. It specifically addressed natural hazard response in case of natural disasters, defining events of earthquake type. The integration of the Smart Building Controller in an EMS (Emergency Management System) for protection in case of earthquakes is depicted in Fig. 4.

![Fig. 4. EMS for Earthquakes – system integration with the SBC](image)

The set of events were defined, then the specific simulation scenario was executed, based on proper policy definition. The presented results concerned testing the SBC operation in an earthquake scenario using models of dedicated virtual devices through the web service definition mechanism in the Simulation Bridge component of the proposed framework.
3.2. Control and monitoring services

This section depicts a case study concerning a normal operation scenario with the Smart Building Controller. This case study (CS2) uses the Smart Building Controller during normal daily operation, specifically controlling climate and equipment in an office building. First, the business scenario is presented then a set of policies is defined. This time, the SBC makes use of scheduled tasks, as opposed to the unexpected events of CS1. Finally, the execution of the considered scenario is detailed.

3.2.1. CS2 business scenario

The following business scenario considers a 25 story building situated in Paris (as per climate concerns) and one of its two window offices facing south on the 19th floor. During the month of March, the outdoor temperature is considered to be in the medium lower values (as per the temperate climate), described as a “chilly” environment, thus requiring the air conditioning unit (ACU) to be turned on at 8:00, with a setpoint of 26°C. Henry arrives at his office at 8:06. When he opens the door, the lighting is automatically switched on and the window shutters are opened. Henry turns on the monitor of his computer (the central unit itself having previously received the turn on command at 7:55). He can see the daily schedule and weather forecast on the computer screen. He finds out that rain is possible at 14:00. He modifies the schedule for lunch, initially set from 12:00 – 13:00, to 12:45 – 1:45.

At 12:45, Henry leaves his office for lunch. When Henry leaves the office, the lighting is switched off. At 13:10, the intelligent building management system determines that the outdoor temperature is higher than 28°C and decides, in order to obtain the desired temperature and to meet energy consumption requirements, to open the window and turn off the ACU. At 13:45, Henry comes back and the lighting is turned back on.

At 16:00, the system determines that the external temperature has dropped below the desired temperature set point. It closes the windows and switches on the ACU. Henry leaves the office at 17:55. Five minutes later, the computer is given the shut down command, the ACU is switched off and the shutters are closed down.

The following elements are present into the room:

- **PresenceOffice**: a proximity transducer device that reads the presence or absence of a person in the room, exposed with a single parameter: Presence01= True (person in room) or False (person not in room)
• **LightOffice**: lighting devices, exposed with a single parameter: \( \text{Pin01}= \text{on} \) (lights on) or \( \text{off} \) (lights off)

• **ShutterOffice**: shutter actuator devices, exposed with two parameters with the same value range, one for each window: \( \text{Shutter01} \) and \( \text{Shutter02} = \text{on} \) (open) or \( \text{off} \) (closed)

• **WindowOffice**: window actuator devices, exposed with two parameters with the same value range, one for each window: \( \text{Window01} \) and \( \text{Window02} = \text{on} \) (open) or \( \text{off} \) (closed)

• **AirConditionOffice**: ACU control device, exposed with six parameters: temperature taking as values positive integers depicting temperature set points, \( \text{mode} = \text{auto, heat or cool} \), \( \text{state} = \text{ON or OFF} \), \( \text{fan} = \text{low or high} \), \( \text{swing} = \text{on or off} \), \( \text{ion} = \text{on or off} \)

• **PC_Henry**: the computer’s power button (actuating device), exposed with a single parameter: \( \text{state} = 0 \) or \( 1 \)

• **TemperatureOutdoor**: a temperature transducer device that reads the external temperature, exposed with one parameter: \( \text{temp} \) taking as values positive integers depicting temperature readings.

**3.2.2. CS2 set of policies**

For the smart building, the normal operation scenario requires definition of scheduled policies and/or specific schedules singular tasks (Fig. 5).

![Policy definition](image)

**Fig. 5. Policy definition**

The scenario incorporates policies that are accessed during working hours and policies that apply after-hours, detailed as follows:

A. **Presence Policy**: A three rule policy named **Policy_Presence** is defined using the Policy Management System (PMS, 2013) as follows:
**Rule 1:** If the proximity sensor detects someone in the room and the lighting is off, then turn on the lights.

\[
\text{ON (PresenceOffice.Presence01==True) IF (LightOffice.Pin01==off) THEN [[LightOffice.Pin01=on]];}
\]

**Rule 2:** If the proximity sensor detects someone in the room and at least one of the shutters are closed, then open both shutters.

\[
\text{ON (PresenceOffice.Presence01==True) IF ((ShutterOffice.Shutter01==off) or (ShutterOffice.Shutter02==off)) THEN [[ShutterOffice.Shutter01=on]]; [[ShutterOffice.Shutter02=on]];}
\]

**Rule 3:** When nobody is in the room and the lights are on, switch the lights off.

\[
\text{ON (PresenceOffice.Presence==False) IF (LightOffice.Pin01==on) THEN [[LightOffice.Pin01=off]];}
\]

**B. High Outdoor Temperature Policy:** A two rule policy named **Policy_Temp01** is defined using the Policy Management System (PMS, 2013) as follows:

**Rule 1:** If the outdoor temperature is higher than 28ºC and the ACU is on, then turn off the ACU.

\[
\text{IF (TemperatureOutdoor.temp>28) and (AirConditionOffice.state==ON) THEN [[AirConditionOffice.state=OFF]];}
\]

**Rule 2:** If the outdoor temperature is higher than 28ºC and the window is shut, then open the window.

\[
\text{IF (TemperatureOutdoor.temp>28) and (WindowOffice.Window01==off) and (WindowOffice.Window02==off) THEN [[WindowOffice.Window01=on]]; [[WindowOffice.Window02=on]];}
\]

**C. Low Outdoor Temperature Policy:** A two rule policy named **Policy_WinOp** is defined using the Policy Management System (PMS, 2013) as follows:

**Rule 1:** If the outdoor temperature is lower than 25ºC and at least one of the windows are open, then close the windows.

\[
\text{IF (TemperatureOutdoor.temp<25) and (WindowOffice.Window01==on) or (WindowOffice.Window02==on) THEN [[WindowOffice.Window01=off]]; [[WindowOffice.Window02=off]];}
\]

**Rule 2:** If the outdoor temperature is lower than 25ºC and the ACU is off, then turn on the ACU on heating mode with a 26 ºC setpoint.

\[
\text{IF (TemperatureOutdoor.temp<25) and (AirConditionOffice.state==OFF) THEN [[AirConditionOffice.state=OFF]]; [[AirConditionOffice.mode=heat]]; [AirConditionOffice.temperature=26]};
\]
D. **After-Hours Policy:** A six rule policy named Policy\_AfterHours is defined using the Policy Management System (PMS, 2013) as follows:

**Rule 1:** If the lights are on, then turn the lights off.

\[
\text{IF (LightOffice.Pin01==on) THEN } [\text{LightOffice.Pin01=off}];
\]

**Rule 2:** If the first window is open, then close the window.

\[
\text{IF (WindowOffice.Window01==on) THEN } [\text{WindowOffice.Window01=off}];
\]

**Rule 3:** If the second window is open, then close the window.

\[
\text{IF (WindowOffice.Window02==on) THEN } [\text{WindowOffice.Window02=off}];
\]

**Rule 4:** If the first window shutters are open, then close the shutters.

\[
\text{IF (ShutterOffice.Shutter01==on) THEN } [\text{ShutterOffice.Shutter01=off}];
\]

**Rule 5:** If the second window shutters are open, then close the shutters.

\[
\text{IF (ShutterOffice.Shutter02==on) THEN } [\text{ShutterOffice.Shutter02=off}];
\]

**Rule 6:** If the ACU is on, then turn the ACU off.

\[
\text{IF (AirConditionOffice.state==ON) THEN } [\text{AirConditionOffice.state=OFF}];
\]

3.2.3. **CS2 set of schedules**

For each policy, a schedule is defined. For Policy\_Presence, Policy\_Temp01, Policy\_WinOp, the schedules applies from 8:00 until 18:00. For Policy\_AfterHours, the schedule applies from 18:00 to 7:50.

A schedule for the computer is also created. This schedule stipulates that the computer’s central unit is to be turned on at 7:55, 5 minutes before the person (Henry) arrives at office and to be shut down at 18:00 when the working hours program finishes.

3.2.4. **CS2 business scenario execution**

Fig. 6 presents a screenshot taken after the execution of the previously defined policies, taking into account their specific schedules.
On March 5th 2013, the action plan has executed the following operations:

- 07:55 – Computer on – Type: Schedule; PC_Henry: state=1
- 08:00 – ACU on (26°C setpoint, fan low, swing off, ionization off) - Type: Policy; Name: Policy_WinOp; AirConditionOffice: temperature=26 mode=auto state=on fan=low swing=off ion=off
- 08:06 – Presence true - Type: Event; PresenceOffice: Presence01=True
- 08:06 – Switch lights on - Type: Policy; Name: Policy_Presence; LightOffice: Pin01=on
- 08:06 – Open shutters - Type: Policy; Name: Policy_Presence; ShutterOffice: Shutter01=on Shutter02=on
- 12:45– Presence false - Type: Event; PresenceOffice: Presence01=False
- 12:45 – Switch lightsoff- Type: Policy; Name: Policy_Presence; LightOffice: Pin01=off
- 13:10 – ACU off- Type: Policy;Name: Policy_Temp01; AirConditionOffice: state=OFF
- 13:10 – Open windows - Type: Policy; Name: Policy_Temp01; WindowOffice: Window01=on Wundow02=on
- 13:45 – Presence true - Type: Event;PresenceOffice: Presence01=True
- 13:45 – Switch lights on- Type: Policy; Type: Policy; Name: Policy_Presence; LightOffice: Pin01=on
- 16:00 – Close windows - Type: Policy;Name: Policy_WinOp; WindowOffice: Window01=off Wundow02=off
• 16:00 – ACU on (26°C setpoint, fan low, swing off, ionization off) - Type: Policy; Name: Policy_WinOp; AirConditionOffice: temperature=26 mode=auto state=on fan=low swing=off ion=off
• 17:55 – Presence false - Type: Event; PresenceOffice: Presence01=False
• 17:55 – Switch lights off - Type: Policy; Name: Policy_Presence; LightOffice: Pin01=off
• 18:00 – Computer off - Type: Schedule; PC_Henry: state=0
• 18:00 – Shutters down - Type: Policy; Name: Policy_AfterHours; ShutterOffice: Shutter01=off & Shutter02=off
• 18:00 – ACU off - Type: Policy; Name: Policy_AfterHours; AirConditionOffice: state=OFF

The normal operation schedules using the Smart Building Controller are executed, consisting of controlling climate and equipment in the considered office building.

4. Viability and Future Prospects on the Virtual Smart Building Service Enterprise

The perspective presented in section 3 aiming to develop a smart building services ecosystem taking into consideration the concept of the Virtual Smart Building Service Enterprise allows the definition of different service concepts. They range from SCADA (supervisory, control and data acquisition) services, intelligent building resource management services, reporting services, energy consumption prediction services, to Smart Building Framework implementation services, protocol adaptor services, all within a service oriented architecture.

The new services installed and used in smart buildings may vary with the customer needs, e.g. monitoring comfort variables and energy consumption, automated control of HVAC systems, predicting and intelligently adapting various functionalities.

The technological advancements allow consumers to supervise and control several types of devices to enhance their comfort and optimize the energy consumption. The smart building service provider will supervise the new service system integration while the service consumers will be granted full control over their system infrastructure.

Different implementation scenarios can be developed for any building that is needed to be evaluated or maintained from a comfort and energy-efficient perspective or for safety purposes. For example, warm season schedules and adaptive policies, cold season schedules and adaptive policies, building parameters monitoring and decision making related to energy consumption optimization and increased level of comfort.

This development and implementation perspective reveals a holistic approach on providing a dynamic platform so that new improvements are continuously developed and integrated along...
with technological advances. This is a new and complex perspective on the integration of the new possibilities powered by IT, innovating services and bringing the service customer in the value co-creation chain.

The new smart building service capabilities offered along with the FCINT platform such as adjusting comfort-related parameters based on predicting building occupant behaviour as well as reducing the building maintenance costs in this process is a very attractive concept. Also, Big Data analysis on the collected data will improve the service consumer satisfaction by allowing the development of new features as well as improving existing ones, as a forum for direct consumer feedback is also available.

Different service outcomes are highlighted and a perspective on value co-creation in the context of the Virtual Smart Building Service Enterprise concept is proposed. Among these, the following can be mentioned: home and office comfort, people safety in case of emergencies, better monitoring and knowledge about building behaviour, policy implementation in case of emergency, statistics on people behaviour and preferences.

Along with the Virtual SBSE, different value propositions can be formulated by the service providers to support customer integration in a complex value co-creation activity chain, such as: remote access for ambient preferences (home and office), remote access to the control and monitoring functions of the smart building, distributed control of devices and centralized monitoring of operational functions of the smart building, open architecture that allows integration with different service providers based on service composition, availability to open different communication channels between service providers and consumers to improve operational efficiency on business processes.

5. Conclusions

This paper addresses specific topics related to engineering services for community in the smart city perspective, focusing on safety and sustainable resources consumption. Today, simulation, control and monitoring applications are employed in many aspects of modern cities, and more developments can be imagined for the future, if the community better understands the challenges and opportunities arising from the interaction between different stakeholders, like city governments and industry players. Meanwhile, the role of the citizen, as an empowered service customer, is more clearly defined and it draws more specific design requirements to engineer services that enlarge the future role of public and private institutions to foster environmental sustainability, education to citizenship, healthcare, or mobility.
Here, required steps to design and develop a service ecosystem dedicated to the *Smart Building Management* solution development is presented, both for control and monitoring, as well as for other functions (services) that co-create value for end users. Through the definition of the Virtual Smart Building Service Enterprise concept, the relation between community service providers and customers is highlighted. The proposed development perspective defines complex services integrated in a larger service ecology, giving the possibility to connect the management of a single building to the management of territorial and social systems, like emergency management, city planning and operations, smart transportation, smart water, smart education, or smart energy.

Such a service ecosystem would include a group of users within the industry sharing their services for use across the group for controlling, monitoring, testing or training. This observation opens a broad range of possible future developments, but it also leads to the formulation of possible limitations. From a technology point of view, future acceptance and integration of the Virtual Smart Building Service Enterprise concept into Smarter City common off the shelf solutions highly relies on the availability of the companies working towards building the Internet of Things to embrace new IT architectures enabling improved computing capabilities in a distributed model.

The paper emphasises the role of the technology platform in service innovation, service composition and delivery, along with a case study related to engineering smart services for safety and energy efficiency and economic sustainability. The practical demonstration to control and manage building facilities via intelligent controllers relies on an already existent open software platform, developed in the service-oriented approach that supports both information integration from different sources and service publication, discovery and integration.

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