A system of cloud-based intelligent controllers used as elements of a neural network for process management

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Abstract: *Building management systems add unlimited intelligence to domestic appliances, hence allowing users to monitor, visualize, and optimize the consumption of electricity, water, heat, gas, etc. There is no need to install additional software – everything needed is available on the smart platform website.*
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1. INTRODUCTION

By definition, Grids are computer resources organized into a network, available through the Internet by using standardized procedures with guaranteed high reliability [1].

- Special emphasis is placed on the presence of a global unified access.
- Users get access to the resources and capabilities they want to achieve (hardware and software).

Cloud Computing puts an accent onto receiving computer service that are rendered upon request through the Internet by using standardized procedures with guaranteed high reliability [2], [3]. Users are not interested in the computer resource behind the service. In particular, computer service could be rendered in the form of computer environment which is to be organized by user according to their preferences. It could be safely assumed that Cloud Computing represents the evolution of the concept for public use of computer services, in which Grids are the intermediate stage. In respect to technical implementation, Cloud Computing is the user access level to distributed computational resources, which is:

- above the level of service provided by the computer resources, which could also be maintained by a Grid;
- focused on what the user wants to do, instead of the way it is provided.

Differences in respect to the configuration of use:

- As Cloud Computing is solely owned, it most often does not solve the issues related to the interaction between resource owners.
- Grid emphasizes the organization and interaction between users (virtual organizations) [4].

Considering the above definitions, the paper presents a platform for intelligent management of – generally said – building installations, which are prevailing within the environment that people inhabit. The platform aims at high-quality management and efficiency of energy and resource consumption by the environment people inhabit almost around the clock.

Some authors present a web services-based approach to integrate resource constrained sensor and actuator nodes into IP-based networks, which feature is its capability for automatic service discovery. For this purpose, they implemented an API to access services on sensor nodes following the architectural style of representational state transfer (REST) [5].

The other research proposed system architecture for load management in smart buildings which enables autonomous demand side load management in the smart grid. That architecture is layered structure composed of three main modules for admission control, load balancing, and demand response management and can encapsulate the system functionality, assure the interoperability between various components, allow the integration of different energy sources, and ease maintenance and upgrading [6].

2. TOPOLOGY OF THE PLATFORM

We present a fully realized experimental system for management of all types of building systems existing in a real property, with the following objectives:

1. To monitor, visualize, and optimize the consumption of electricity, water, heat, gas (if there is gas supplied to the property), etc.

2. To provide optimal conditions for a comfortable living or working environment (depending on the intended use of the facility) in a solid opportunity for saving electricity, heat and/or energy used for heat generation (in the particular property/building).

3. To create a model for management of all forms of energy consumption available in the property – electric, heating, water (hot and cold), gas (a special case of energy carrier), solar power (generating heat through thermal panels or electricity through photovoltaic panels), wind power generating electricity, systems for surplus energy storage – thermal energy stored in heat accumulators; wind and solar energy stored in a system composed of a battery unit (or units) and a hybrid inverter.

4. To develop an intelligent (scheduled) and autonomous energy management system controlling all forms of energy use and guaranteeing roughly three time lower consumption; remote access to the power consumption status of any device in the property as well as to the conditions in any room at any time (temperature, humidity, lighting, blinds, detection of human presence, etc.); automatic irrigation system (including drip irrigation) for lawns and gardens. The activation and data access must be possible via any web browser using portable devices (phones, tablets, laptops) or TV sets, regardless of the operating system.

The modular control system provides automation, monitoring, reporting, and statistics for any operation performed within our living space, thus way converting it into a smart space that „thinks” instead of us, informs us and – depending on the model – performs the tasks it is assigned. The Smart Space covers a range of enclosed environment types, such as homes, offices, business centers, warehouses, shops, factories, workshops and plants, kindergartens, schools, universities, gymnasiums, etc. It also covers a range of free and open spaces – private gardens, residential districts, public parks, aqua parks, playgrounds, etc.

The system is compatible with very inexpensive wireless end-effectors, some of which are designed to be manually controlled. Once placed under the management of the specialized grid controllers (referred to in the text as Smart Space Bridge – SSB), prior to which they do not need to undergo any change, they start performing intelligent tasks, such as automation, metering, monitoring, and reporting. These low-cost devices' price range from 10 to 40 BGN; even though they are of different brands, they are usually produced by the same manufacturers, and are available for purchase in stores.

Several different types of Internet-based smart controllers are integrated into the system. To them, different types of actuators and mechanisms are connected either via wired of wireless connection (e.g. solenoid valves, circulating pumps, electric valves with actuators, electro-hydraulic controls for valves, contact relays, and sensors for temperature, humidity, pressure, etc.).

Fig. 1. Topology of the system's communication environment.

The SSB controllers installed in a grid (in terms of topology) communicate with a wide range of wireless devices, which can be generally divided into two categories: Receivers and Transmitters.

Receivers are devices that respond to commands:

- Electrical outlets: on/off control of consumers or appliances
- Lamp holders: switch on/off bulbs or lighting circuits
- Electric blinds: open/close blinds
- Radiator valves and/or converters: automatically adjusts the heating as required to maintain the desired temperature.

Transmitters are devices that have the capability to send out information (either periodically or upon impact):

- Thermometers: periodically send data of temperature and humidity level.
- Counters: electricity, water, gas, etc. meters with pulse output.
- Switches: send commands to turn on/off a specific consumer or device.
- Detectors: detect motion, fire, day/night (light level), etc.

Any of these devices, if present in our Smart Space, can be controlled by the platform. Via transmitters, the data is being transferred into the cloud; as a result of the automatic tasks pre-assigned by user, the platform develops a series of operations; they are sent to the grid controllers, which in turn forward commands to the terminal receivers.

Since a large proportion of the above-mentioned terminals interact with each other via radio waves, the system combines several advantages:

- reduced installation costs;
- no additional technical expenses;
- no wiring;
- no need for technically competent human resources (straightforward to set up);
- freedom to move.

There is another type of specialized controllers – GSC – that can also be connected to the platform; they usually have between 2 and 8 (including switching) contacts and can directly control at least 1 kW electric consumers, 1 to 4 temperature and/or humidity sensors, and alarm input for connecting an external sensor. The GSC controllers connects to the Internet through RJ-45 network connector. They have built-in DHCP and are charged by a 12V charger.

3. RESULTS AND CONCLUSIONS

The platform adds unlimited intelligence to domestic appliances, which allows us to manage them wisely, to reduce energy costs and achieve savings. There is no need to install additional software on the user's PC, phone or tablet computer in order to achieve their desires and ideas of the Smart Space they want. Everything needed is available in their user account on the website of the platform.

The platform analyzes and stores every single data, both sent and received, hence allowing the user to check anytime (through its reporting function) what happened when, and who caused it (i.e. whether the lights were turned on automatically or manually through a mobile device).

Here are a few examples of automation easily implementable through the platform:

- When you leave on vacation, the platform will simulate your home being lived in by periodically turning the lights on and off.
- When it gets dark, the platform will turn on the lights in the garden.
- As you walk through the house, the platform will detect your motion and turn the lights on and off to shine your way for you.
- When it rains, the platform will close the blinds and cover the swimming pool.
- At weekends, the platform turns on the coffee maker for you at 7:30 AM; on weekday mornings it doesn't do that as you would drink coffee at work.

EXPO 1 / HALL / TERMO HALL		
Time Zone:	Europe/Sofia	
Day	27/05/2015	
	C°	H_2O
00:XX	16.1	71
01:XX	16	71
02:XX	16	71
03:XX	15.9	71
04:XX	15.8	71
05:XX	15.7	71
06:XX	15.7	71
07:XX	15.6	70
08:XX	15.6	70
Max value:	16,1	71
Min value:	15,6	70
Average value:	15,8	71

Fig. 2. Format of exported data (temperature and humidity).

This specific genuine research system manages the installation of a smart building equipped with the following heat sources/generators: solid fuel boiler, pyrolysis boiler, pellet stove, gas boiler, air to water heat pump (2 pcs), solar thermal system with thermal panels (6 pcs), local electric heaters with local thermostats. The heating system consists of 40 units, 10 of which are convectors that can also be used to cool air. Its total installed capacity is about 270 kW. A thermal battery (consisting of a 1600L buffer storage vessel and 600L boilers) is also integrated into the system.

In selection of heat-generating power, priority is given to the sources that are most cost-effective: management of air to water heat pumps – total 27 kW, pyrolysis boiler – 35 kW, pellet stove – 25 kW.

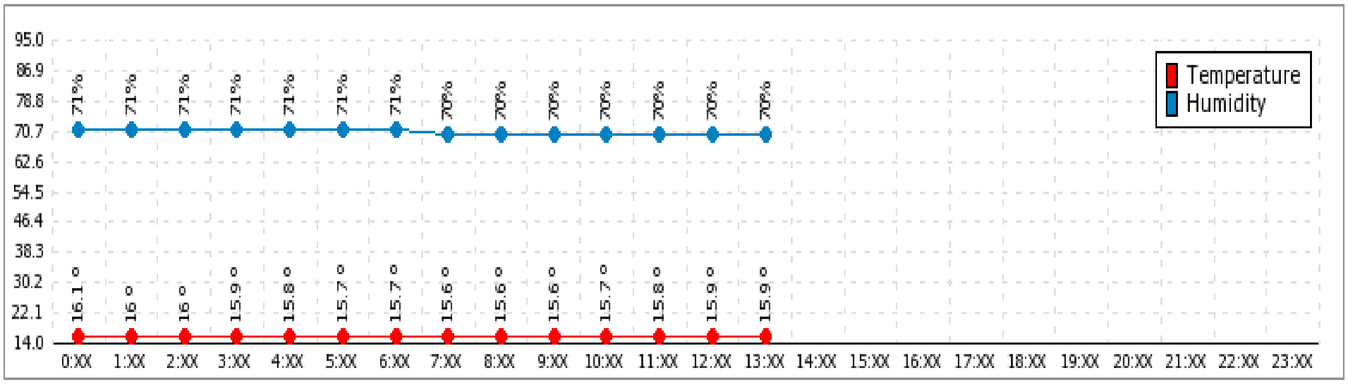

Fig. 3. Single point temperature and humidity data displayed in a graphic form.

The installed controllers and the platform allow for:

- remotely programmable regulation of optimum room temperature and humidity for each one of the 15 rooms of the house;
- metering of electricity and heat consumption;
- measuring water used in household activities and water used for yard and garden irrigation (each one of the 24 circles referred to as a separate irrigation system);
- redirecting the solar thermal energy to water or domestic heating;
- water pressure monitoring;
- turning on exterior lights at a scheduled time;
- when not at home – turning off the electric supply to the facility;
- when it rains – turning off the automatic irrigation system.

Right at this moment, 48 switches are being managed within the heating and irrigation sectors and the central management of the Smart House. In the sensor sector, information from over 20 points is received, and 9 heating circuits with over 25 radiators – valves, blowers and pumps – are automatically controlled. Comprehensive and detailed statistics are available for each parameter, consumer and/or point added to the platform for management and control. Another 5 kWp accumulating photovoltaic system with a hybrid inverter is being integrated, which makes it possible to store "night" electricity. In cloudy weather, it will expand the use of the cheaper off-peak power and will reduce the overall maintenance costs of the property. A module of 2 kW wind generator will also be integrated into the system, and will be added to the battery storage of renewable energy.

The analysis of the collected data outlines the tendency of the platform to generate cost savings of around 60% of the amount of energy required to maintain comfortable conditions under the given exploitation regime; the monetary value is even higher, as the system uses low-cost “night” energy, either supplied at the cheaper night rate, generated by the Sun, or accumulated beforehand. It is worth mentioning that the system works without any human intervention. The entire information for statistical analysis and generation of other models for property management and reliable operation is also available.

The proposed structural model of building automation system provides a secure living environment and serves as an example of widely affordable management of the most common domestic and office smart grids. It is also an example of energy efficiency achieved with low-cost resources and topology.

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