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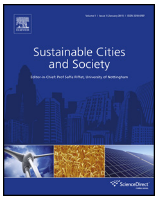

Identifying services for short-term load forecasting using data driven models in a Smart City platform

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ABSTRACT

The paper describes an ongoing work to embed several services in a Smart City architecture with the aim of achieving a sustainable city. In particular, the main goal is to identify services required in such framework to define the requirements and features of a reference architecture to support the data-driven methods for energy efficiency monitoring or load prediction. With this object in mind, a use case of short-term load forecasting in non-residential buildings in the University of Girona is provided, in order to practically explain the services embedded in the described general layers architecture. In the work, classic data-driven models for load forecasting in buildings are used as an example.

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1. Introduction

The concept of Smart City appears due to the mobilization of people to the cities. This increase of people has an impact on city services such as transportation, utilities, communications, waste management, health services and much other. In order to avoid services degradation, and have an idea of the effect of such increase of people for a particular service, it is necessary to manage each service by constantly monitoring it. Therefore, it is needed to provide the system with mechanisms for collecting data. This is the first step towards getting to a Smart City. But what it really makes the city smart is to process and analyse the data and returns as response some kind of action to ensure the provision of services at satisfactory levels of quality. Hence, it is necessary to integrate these monitoring devices with the applications that perform the analysis of this data and are able to provide an action (da Silva et al., 2013).

The synergy of computational and physical components, specifically the use of cyber-physical systems (CPSs), led to the advancement of such integration. At different scale, neighbourhoods, communities or buildings can also be considered large CPS continuously operated accordingly to demand affected by the activities of users. As important is to know physical system constraints as consumer's behaviour, and interactions between both. Major Information and Communication Technology (ICT) vendors have made efforts for developing Smart City transversal platforms oriented to integrate city information and making it available to end-users. On the other hand, the utilities (water, electricity, gas, etc.) have their proprietary solutions specifically designed to operate and supervise these infrastructures and providing managing and billing services. This work falls in between these two scopes and shares the IoT (internet of Things) vision, focusing not only in making data available but also providing the required services to facilitate advanced data analysis, monitoring and assessment procedures in the domain of urban energy distribution and consumption. This paper aims to analyse a specific use case in order to identify services that are required in a platform that supports the development of energy monitoring and assessment applications for urban infrastructures.

Several general architectures for Smart Cities are proposed in the literature, but few examples of their implementation and how to embed services on them are given. According to the existing Smart City architectures, the present work proposes an implementation of a practical case, a complete short-term load forecasting system, explaining the singularities layer by layer trying to cover this gap.

The utilities are the main users of the load prediction systems, who, thanks to the load prediction, manage the maintenance and the control of the distribution systems, buying fuel at the best price or shaping the consumption curve in order to have a flat consumption curve following several strategies. So, this is a tool for the

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utilities who manage the distribution systems, and in particular to help them to forecast the electrical consumption.

2. Context and related work

In the bibliography, taking into account the existence of different visions, several definitions of Smart City are found. In Giffinger and Pichler-Milanović (2007) the Smart City is defined as "a city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens". Otherwise in Bowerman et al. (2000) it is said that Smart City is "a city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rail/subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens". The paper (Washburn et al., 2009) says that "the use of Smart Computing technologies to make the critical infrastructure components and services of a city which include city administration, education, healthcare, public safety, real estate, transportation, and utilities more intelligent, interconnected, and efficient".

Some papers, like Nam and Pardo (2011), coincide that Smart Cities are composed by three main dimensions. The first one is the technology dimension, where several technologies are used to monitor, control and share in the city processes. The second one is the human dimension, where creativity, relationships, education and knowledge are the base of the human infrastructure to provide social benefits to the Smart City. The third one is the institutional dimension, where the administration promotes regulations, policies and community participation to grow properly and sustainably.

On the basis of the reviewed works, the common Smart City challenges are:

- Establish a base Smart City architecture to provide a common framework for the sector.
- Dispose and extend standardized Smart City policies that lead to the growth and the proliferation of Smart City services and initiatives.
- Design a list of the essential Smart City services such as Smart water, Smart Governance, Smart buildings, etc.
- Define the basic guidelines in order to perform operations, maintenance, improvements and the scalability in the Smart Cities.

Therefore, it has sense to contribute in the field with a suitable Smart City architecture, selected for developing the services oriented to consumption prediction. It provides the basis where the smart services are going to operate. The following paragraphs summarize different works done in the field of Smart Cities covering proposed architectures and services implied and some of them particularized for short-term load forecasting (STLF). From the point of view of services, there are some papers cited.

A complete guide for design the Smart City architectures and all the functionalities from the data point of view is proposed in Wenge, Zhang, Dave, Chao, and Hao (2014). A summary of the main issues of the application systems and the difficulties and challenges in the construction of the Smart City is presented in Su, Li, and Fu (2011). A broad view of energy services and their usage, functionality and development challenges are explained in Karnouskos, Silva, and Ilic (2012). In order to improve operations and maintenance, reduce the cost of operation, provide enhanced energy management capabilities and provide scalability in the Smart City architecture a guidelines are highlighted in Al-Hader, Rodzi, Sharif, and Ahmad (2009). Several Smart City architectures and their requirements are exposed and commented in da Silva et al. (2013). The work (Morvaj, Lugaric, & Krajcar, 2011) comes up with a model for analysis of interactions with a Smart City, providing a larger scale simulation among several Smart City systems. A wide survey of technologies, protocols, and architecture for an urban internet of things in Smart Cities is shown in Zanella, Bui, Castellani, Vangelista, and Zorzi (2014).

So, there is no defined criteria about the number and the function of layers of the Smart City architecture. The work (Komninos, 2006) presents a three layers architecture: information storage layer, application layer and user interface layer. The paper (Al-Hader et al., 2009) suggests a five layers architecture: smart infrastructure, smart database, smart building manager, smart interface and integration layer. The publication (Anthopoulos & Fitsilis, 2010) proposes a five layers architecture: stakeholder layer, service layer, business layer, infrastructure layer and information layer. In Filipponi et al. (2010) the Smart City architecture is divided in two layers: knowledge processors and semantic information brokers. The paper (Lugaric, Krajcar, & Simic, 2010) proposes a Smart City architecture with three parts: the physical network, the communications infrastructure and the flow of information. The study (Al-Hader & Rodzi, 2009) divides the Smart City in two layers: monitoring layer and development layer. The work (Wenge et al., 2014) proposes a five layers architecture: data acquisition, data transmitting, data storage, support service, domain service and event application.

In relation with Smart City services, a short-term load forecasting model for non-residential building on the basis of occupancy and temperature is presented in Massana, Pous, Burgas, Melendez, and Colomer (2015). A principal component analysis is used for monitoring the electric consumption of buildings in Burgas, Melendez, Colomer, Massana, and Carles (2014). In order to organize the power production of distributed generation sources in relation with energy storage system and reduce the operational costs of microgrids a smart energy manager system is provided in Chen, Duan, Cai, Liu, and Hu (2011). In the work Lund, Andersen, Østergaard, Mathiesen, and Connolly (2012), the need to include the cogeneration power generation in electricity balancing and grid stabilization is pointed out. The benefits of a home energy control box for optimizing energy consumption from electrical vehicle charging in residential buildings are seen in Mets, Verschueren, Haerick, Develder, and De Turck (2010). In Krajačić et al. (2011) an energy system planning which incorporates renewable energy services, energy storage technologies and system regulation strategies is provided. A smart energy distribution and management system for monitoring power consumption and users' situation and controlling appliances is presented in Byun, Hong, Kang, and Park (2011). An energy information system (real data acquisition, visualization, analysis and switching) which admits the integration of several sensors is provided in Kunold, Kuller, Bauer, and Karaoglan (2011). The paper (Castro, Jara, & Skarmeta, 2013) describes a smart lighting solution which allows the integration of the communications and logic on the current street lighting infrastructure. A design and implementation of occupancy sensor platform for individual offices is presented in Agarwal et al. (2010).

Taking into account the energy signatures, in Aoun (2013) the importance of energy signatures which can help to improve the energy efficiency and monitor the consumption, is pointed out. The use of the energy signatures in order to evaluate the energy performance of chillers using several design options and operating strategies is seen in Yu and Chan (2005). In Rabl and Rialhe (1992) the addition of occupancy as a variable in energy signature model PRISM is analysed.

With regard to baseline models and measuring and verification methods, the work (Heo, Choudhary, & Augenbroe, 2012) proposes

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