Chapter 16
Combining BIM, GIS, and IoT to Foster Energy Management and Simulation in Smart Cities

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ABSTRACT

This chapter presents a novel distributed software infrastructure to enable energy management and simulation of novel control strategies in smart cities. In this context, the following heterogeneous information, describing the different entities in a city, needs to be taken into account to form a unified district information model: internet-of-things (IoT) devices, building information model, system information model, and georeferenced information system. IoT devices are crucial to monitor in (near-) real-time both building energy trends and environmental data. Thus, the proposed solution fulfills the integration

DOI: 10.4018/978-1-6684-7548-5.ch016

and interoperability of such data sources providing also a correlation among them. Such correlation is the key feature to unlock management and simulation of novel energy policies aimed at optimizing the energy usage accounting also for its impact on building comfort. The platform has been deployed in a real-world district and a novel control policy for the heating distribution network has been developed and tested. Finally, experimental results are presented and discussed.

INTRODUCTION

Urban population have reached more than 54% of the total global population (World Health Organization, n.d.) and buildings represent nearly the 40% of total energy consumption. New control policies to optimize energy consumption in cities that include buildings and grids (e.g. power and heating distribution networks) are needed in order to reduce the overall energy consumption. For example, smoothing thermal energy peaks includes information on building energy profiles as well as grid topology and features to determine their actual effect on network infrastructures. This knowledge can be made accessible by means of ubiquitous sensors installed in buildings as well as in energy distribution networks. In the case of district heating, it is important to identify building energy profiles as well as distribution networks topologies and characteristics to reshape thermal energy peaks. Such reshaping has an effect on buildings air temperature profiles which can be carefully assessed to maintain an optimal level of user comfort.

Exploiting the Internet-of-Things (IoT) (Ashton, n.d.) communication paradigms (Giusto, Iera, Morabito, & Atzori, 2010), monitored data can be made available at the utility control centers. With such a data it is possible to implement smart control policies on cloud or ICT cluster infrastructures. Furthermore, IoT eases the integration of heterogeneous data sources that can be exploited to develop smarter policies. In such a way, Building Information Models (BIMs) (Eastman, Eastman, Teicholz, & Sacks, 2011) and Geographical Information Systems (GISs) (Tomlinson, 1968) can be integrated with sensor data. BIMs are 3D parametric models that describe all the elements of a building reporting construction and physics characteristics of the element. BIM allow to perform energy simulations that can be used to evaluate the impact of thermal reshaping on indoor air temperature. Such a simulation can be compared with temperature profiles provided by indoor sensors to tune energy models that can be used to evaluate policy impact on buildings where environmental sensors are not deployed. Researchers have proposed many frameworks in the last decades to exploit IoT technologies at building and house level (Kamilaris, Pitsillides, & Trifa, 2011) (Patti E., et al., DOI: 10.1109/JSYST.2014.2302750) (Bonino, Castellina, & Corno, 2008), and software solutions have been proposed to enable interoperability among various data formats and protocols (Da Xu, He, & Li, 2014) (Athanasios, Gialelis, Alexakos, Georgoudakis, & Koubias, 2006) (He & Da Xu, 2014). However, the integration of district models with sensor data remains a challenge.

In this chapter, we present a distributed IoT platform able to collect, process and analyze energy consumption data and structural features of systems and buildings in a district. In particular, data from Building Information Models (Eastman, Eastman, Teicholz, & Sacks, 2011) (BIMs), System Information Models (Brundu, et al., 2015) (SIMs) and Geographical Information Systems (Tomlinson, 1968) (GISs) are interconnected and enhanced by historical and (near) real-time data collection from heterogeneous IoT tools. These instruments are installed across the district to track and control the energy delivery systems (both heating and power). The proposed solution exploits data from sensors installed