EDITORIAL

Smart cities and cloud computing: Introduction to the special issue

Guest Editors
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The special issue "**Smart Cities and Cloud Computing**" of the *Journal of Smart Cities* focuses on smart city solutions that are deployed over various types of cloud environment and discuss challenges and solutions related to the use of cloud computing, and mainly the migration of smart city services to the Cloud.

The papers included are based on experiments that highlight how cities can take advantage from cloud based solutions in infrastructure, platforms and application (IaaS, PaaS, SaaS), lessons learnt from experimentation with cloud platforms, obstacles and enablers in using cloud technologies, and changes to applications and e-services along their migration to cloud environments. Some contributions also offer recommendations and guidelines to public authorities to help them in developing smart city services with cloud computing and make the required internal organisational changes to this end. Six papers and contributions by twenty-two authors are selected for the special issue. Following an introductory paper on smart cities and cloud computing, two papers discuss platforms and cloud-based environments for the deployment of services, two papers focus on cloud-based applications and big data that reveal trends and behaviours in smart cities, while the final paper looks at the challenging issue of data security in cloud-based environments.

The paper "**Smart cities and cloud computing: lessons from the STORM CLOUDS experiment**", by Christina Kakderi, Nicos Komninos and Panagiotis Tsarchopoulos, looks at the advantages that the cloud computing paradigm can offer to city governments for the deployment of smart city applications and services. The advantages are related to cost reduction, quality of e-services provision, enriching skills and infrastructure by outsourcing, adopting more efficient management of IT resources, and managing the large amount of heterogeneous data that are produced by the functioning of cities. The paper examines how these advantages appeared in the STORM CLOUDS project and its smart city experiments with respect to various tasks that were needed to develop or migrate applications to the Cloud. Main tasks for cloud-based deployment of smart city applications include the development of the cloud environment to host the applications, the portfolio of smart city applications and services, the roadmap for the migration of public services to the Cloud, and the business models for scalability and sustainability. The conclusions discuss both the general advantages of cloud computing and some new scientific directions and future challenges with regards to smart cities and cloud computing, and the specific lessons learnt from the platform created and smart city services deployed in the framework of the STORM CLOUDS project.

The paper "**Storm Clouds Platform: a cloud computing platform for smart city applications**", by Marco Battarra, Marco Consonni, Samuele De Domenico and Andrea Milani, describes a platform for running application services and the needed resources to be activated on-demand. In principle, any cloud-based application can run on a public cloud, like Amazon WebServices™ or Microsoft® Azure, which provide computational resources on a pay-per-use basis. However, there are some disadvantages in these large scale clouds due to their proprietary and global nature. Vendor lock-in is a problem, together with the lack of control on the location where applications run and

data are stored. This is an important barrier to cloud-based smart city solutions, in particular when applications manage personal data and the provider has legal obligation for securing data privacy. Given these challenges, the paper presents a new cloud computing platform that was developed on open-software components. It can be used either for implementing private clouds or for porting smart city applications to public clouds. The platform is based on the OpenStack, an open source software for creating private and public clouds, and offers a layered architecture in which the Infrastructure as a Service layer (IaaS) works as the foundation of the whole system. The IaaS layer provides basic IT capabilities like computing services (e.g., Virtual Machines), storage services (e.g., Virtual Volumes) and networking services (e.g., Virtual Networks) enabling the implementation of upper layers, such as the Data Service layer, the Access layer, and the Platform as a Service layer. The platform has been developed and tested successfully in the STORM CLOUDS project and all the software components used for the implementation are available under an Open Source Software license.

The paper "**Social network services for innovative smart cities: the RADICAL platform approach**", by Fotis Aisopos, Antonios Litke, Magdalini Kardara, Konstantinos Tserpes, Pablo Martínez Campo and Theodora Varvarigou, presents another platform for cloud-based smart city applications. The RADICAL platform is a software stack that enables the combination of social network services and Internet of Things (IoT) in the context of innovative smart city solutions. The benefits of combining social networking and IoT in smart cities have been discussed in the literature, yet there is no easy way to develop, customise, deploy and operate such services. The RADICAL platform focuses on this challenge and makes possible to combine multi-sensory and socially-aware services for smart city services. Core component of the platform is a Virtual Machine mechanism which works in a sophisticated cloud environment. The architecture of the platform includes three distinct layers: from top to bottom, the Service Application layer, the Platform layer, and the Data Source layer, where IoT devices, smartphone city apps and various Social Networks provide data. Eight pilot services were tested upon the RADICAL platform dealing with cycling safety, products carbon footprint management, object-driven data journalism, participatory urbanism, augmented reality, eco-consciousness, sound mapping in the city, and crowdsourcing for collecting movement information from citizens smartphones. A large number of citizens from different countries were actively involved in the co-creation, validation and evaluation of the platform, using Living Lab methods for collaborative product development.

The paper "**Migration of applications to the Cloud: a user-driven approach**", by Anastasia Panori, Agustín González-Quel, Miguel Tavares, Dimitris Simitopoulos and Julián Arroyo, focuses on the migration of existing smart city services to cloud infrastructure (IaaS), the selection of most suitable applications, as well as their adaptation to fit in the new cloud environment. The paper presents the main findings of a migration process that has been followed in the cities of Agueda (Portugal), Thessaloniki (Greece) and Valladolid (Spain). The migration process consists of four stages, which include actions dealing with the selection of applications/services to be migrated to the Cloud, technical or procedural problems related to adaptation of the applications to cloud environment, and the migration itself of applications to the Cloud. The definition of monitoring indicators for assessing the results of the migration process constitutes an additional aspect of the proposed procedure. A roadmap is designed that codifies the main instances of the migration process. The paper discusses the three case studies where a migration process took place and offers some advice that might guide cities and city governments to transfer applications and services they provide to cloud environments and take advantage of the cloud computing paradigm.

The paper "**Cloud-based architectures for geo-located blogosphere dynamics detection**", by Athena Vakali, Stefanos Antaris and Maria Giatsoglou, focuses on microblogging content under cloud-based infrastructure. Social networking data emerge rapidly and crowd-driven big data streams are valuable for detecting trends, opinions and citizen behaviour in smart cities. This type of information is of major importance, due to the fact that trends can be utilised to spot collective emergent or evolving patterns and phenomena. However, in such cases, conventional data mining approaches are inadequate to deal with the dimensionality and scalability of data. The Cloud4Trends framework, proposed in the paper, for collecting and analysing geo-located microblogging content under cloud-based infrastructure addresses this challenge. The proposed process involves three series of tasks: (i) collection of data in a streaming manner from Twitter as well as from a pool of selected blogs focused on a number of

geographic areas, (ii) application of an online data clustering method to detect trending topics, and (iii) refinement and ranking of clusters that trends are detected and visualised. The paper shows that Cloud4-Trends offers a viable solution for online social web geo-located and time-related data mining applications, enabling massive data analysis and reducing the need for real-time applications data processing time.

Finally, the paper "**Cloud computing security: protecting cloud-based smart city applications**", by Alkiviadis Giannakoulias, discusses a key challenge to all cloud-based solutions, that of data security. This is a major concern in cloud computing as such environments offer scope for intruders to attack. Cloud computing security is a rising sub-domain of cyber or computer security and refers to a broad set of policies, technologies, and controls used to protect data, applications, and the cloud infrastructure. Security issues related to cloud computing can be classified in two categories, those of cloud service providers and those of cloud users and customers. In particular, the paper focuses on security issues that arise when public sector organisations consider transitioning to an IaaS cloud. The paper examines legal implications; regulatory and standards compliance; vulnerabilities in virtualisation technologies; data integrity issues; and security checks to be performed on the services prior to their movement to the Cloud. The paper lists and explains twenty-one different types of cloud computing security threats, from ease of use to vulnerable data transmission, insecure APIs, malicious insiders to data loss, data breach, and authentication and authorisation. Then security recommendations and the virtualisation of security are presented. This analysis of security challenges leads to a series of recommendations concerning the operating system and firewall software, introspection in public deployment models, regular checks for new updates, and channelling in-going and out-going traffic to virtual machines.

Altogether, the six papers of the special issue discuss three main pillars of developing or moving smart city applications and services to cloud environments. First, the design and deployment of the cloud environment that will host the applications, and the related issues of data management, security, interoperability, second, the selection and adaptation of applications to fit with the type of the cloud environment selected (IaaS, PaaS, SaaS), and third, the use of data mining and analytics to gain insight from the existence of large volume data on the Cloud. These three dimensions of cloud-based smart city applications and services should be addressed concurrently, taking into account interdependences, interoperability, and adaptation of applications to the type of cloud.