Smart Cities

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I. INTRODUCTION

In the coming years, cities are expected to deal with an increasing number and type of services for their citizens, all having to do with overarching goals such as sustainability, environment, quality of life, energy saving, just to name a few. As the population living in urban areas is expected to double by 2050 [1], there is a general consensus that any new process will require more than just an incremental upgrading of the cities' organization, infrastructure, and services provided to its citizens. With this in mind, to achieve the challenging goals mentioned above, drastic changes and disruptive innovations are required that involve a multitude of new technologies relevant to various disciplines such as architecture; computer science; civil engineering; electrical, electronic, and telecommunication engineering; social science; medicine; and behavioral science. These technologies need to be successfully employed for the development of suitable modeling tools and smart solutions of such sociotechnical systems, allowing the development of attractive, inclusive, sustainable, safe, resilient, and agile cities.

This special issue brings together recent international research on one of the most challenging and multidisciplinary subjects of present and future engineering, architectural, medical, economic, information, and social sciences: the smart city paradigm.

Such technologies are today labeled with the ubiquitous word "smart." Technology, however, has always been "smart," so we feel it is worth clarifying that within this context this adjective serves to underline the widespread use of information and communication technologies (ICTs), sensors, and intelligence, e.g., software embedded in the various parts, components, and infrastructures forming an urban area. In this complex and challenging picture, we label people living in the city or using its facilities as "smart" as well, in that they own portable smart devices communicating with existing ICT networks, which are instrumental to the accomplishment of such a goal: think, for instance, of the approach being pursued in many parts of the world aimed at increasing the awareness of the urban environment and at enhancing the interaction with its inhabitants.

Holistic, multilayer approaches integrating technological, societal, and political dimensions are, therefore, necessary to effectively merge all the stakeholders and players of a complex living area: city users, multilevel governance, companies, academia, and urban service providers [2]. New commodities such as open data are required to create value not limited to just the financial dimension, but also extended to public, societal, education, healthcare, among others. Standards, metrics, and methodological frameworks associated with technologies will allow reproducibility, dissemination, traction, and acceleration from results gained by pioneering metropolises, regions, and countries. This emphasizes the importance of getting feedback analysis from pilot project results, which this issue aims to present and discuss. New ways of interactions between the players of this new smart city business have to be explored, to get a synergy between the centralized top–down, participative bottom–up, and collaborative transversal modes to create more value from fewer financial resources, and a better acceptance and efficiency of deployed solutions.

In this view, we feel that the emerging prototype for a smart city is one of an urban environment with a new generation of innovative services for transportation, energy distribution, healthcare, environmental monitoring, business, commerce, emergency response, and social activities

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frequently interacting with each other thanks to ICT devices and solutions. Enabling the technology for such a setting requires a viewpoint of smart cities as cyber–physical systems that include new software platforms and strict requirements for mobility, security, safety, privacy, and the processing of massive amounts of information [3]. In this framework, the energy, transport, and ICT industries will, therefore, receive a strong motivation to work with municipalities to combine their technologies to address the relevant cities' requirements [4]. This is expected to foster the development of innovative, integrated, and efficient—smart—technologies, which place cities at the center of innovation. As a matter of fact, this is what this issue aims to illustrate.

II. OVERVIEW OF THE SPECIAL ISSUE

This issue presents some of the most recent advances and technical solutions focused on the implementation of the smart city paradigm. In particular, this Special Issue addresses topics such as data collection and management, smart/sustainable energy systems (including smart grids), infrastructures and relevant technologies, mobility, transportation, e-health and social factors, citizen involvement, and collaborative economy. The topics have been addressed jointly by teams of scientists and research engineers who, in some cases, work at different institutions or companies; we believe this adds to the value of this Special Issue. All papers are application driven and include some solutions proposed by the authors with reference to advancing the state of the art. Another objective of the issue has been to emphasize the type of technology and methodological approaches that are common to most of the subjects dealt with. Methodological approaches are presented with reference to field results. Smart cities is a relatively new subject, therefore the typical survey, tutorial, or review style is somewhat limited in some papers in this issue. Further, this Special Issue supports the concept that the smart city paradigm implementation can only be achieved with local government, citizens, academia, nongovernmental organizations (NGOs), and industry working together toward a common goal.

This Special Issue starts with a group of papers dealing with one of the most important problems that a smart city needs to cope with: urban mobility. The first paper, "Transactive control in smart cities" by Annaswamy *et al.*, deals with the quality of urban mobility by exploring the use of dynamic tariffs; in particular, the concept of feedback through economic transactions—transactive control (TC)—is applied. Two examples are given in this paper, the first of which is the synthesis of dynamic toll prices with the goal of reducing traffic congestion on highways; sociotechnical models combining behavioral models of drivers and traffic-flow models, together with real-time traffic information obtained from on-road sensors are used to determine the TC strategies. The second example of TC is in the context of mobility on demand, where new modes of transportation, other than private and public, are being proposed, providing a wide range of options for passengers and where TC strategy to regulate the achievable performance around desired values is proposed. The second paper, "The price of anarchy in transportation networks: Data-driven evaluation and reduction strategies" by Zhang *et al.*, deals with increasing transportation network efficiency. This is analyzed by making reference to two different routing policies, the selfish user-centric routing one and the socially optimal system-centric one; the price of anarchy (PoA) index, defined as the ratio of the total travel latency cost under selfish routing over the corresponding quantity under socially optimal routing, is used to achieve efficiency increase of transportation networks. A case study using extensive actual traffic data from the Eastern Massachusetts road network is presented, where the PoA is estimated from data of a complete model of the transportation network, including origin–destination demand and user preferences. The high PoA found in this study motivates the continuing development of connected automated vehicle technologies to automate routing decisions, thus achieving social optimality. The increasing impact that new mobility services have on traffic patterns and transportation efficiency, in general, is dealt with in the third paper, "Information patterns in the modeling and design of mobility management services" by Keimer *et al.*, where the authors investigated how specific information structures imposed by these services can have a profound impact on the traffic behavior. Nonlocal partial differential equation models are used to illustrate the generality of the framework, and, in particular, its ability to integrate models with nontrivial mathematical features. Mathematical modeling is, hence, exploited together with data from ubiquitous sensors in this group of first three papers dealing with urban mobility along with sociotechnical models.

Services that can be delivered to urban environments through big data generated by the public's smartphones creating a new relationship between a city and its infrastructure is a key topic for smart cities, and this is the subject of the fourth paper, "Crowdsensing framework for monitoring bridge vibrations using moving smartphones" by Matarazzo *et al.* In particular, the paper tackles the problem of assessing whether digital data, produced by ubiquitous smartphone sensing, can supply bridge condition information cost-effectively, thereby creating a new relationship between a city and its infrastructure, a problem that is in part dealt with also in the last paper of this Special Issue.

The next three papers focus on energy as one of the main pillars of smart cities, a subject of utmost relevance when sustainability is involved.

As generally accepted, the electric smart grid is considered one of the key enablers for the implementation of the smart city paradigm, and it is therefore not surprising that the smart grid is involved—in part or exclusively—in all three of them. The fifth paper, "Versatile modeling platform for cooperative energy management systems in smart cities" by Hayashi *et al.*, presents a modeling platform, including cooperative energy management systems (EMSs), which reproduces the model of a smart distribution network by using various data types obtained from controlled devices, meteorological stations, and human behavior. The novelty of the proposed EMSs is represented by the accomplishment of data acquisition and functionalities in cyber space and that the proposed platform is widely applicable to energy issues in different cities, including industrial, commercial, and residential districts. The sixth paper, "Smart (electricity) grids for smart cities: Assessing roles and societal impacts" by Masera *et al.*, first discusses the impact that smart grid deployment has, in different respects, on smart cities' structure and development, and then presents a methodology based on European Union (EU) projects previously carried out at the European level for an extended cost benefit analysis, able to go beyond the sole financial aspects. The fact that the conceptually illustrated methodology can naturally be expanded to smart cities is interesting and in line with the aforementioned concept. The seventh paper, "City-friendly smart network technologies and infrastructures: The Spanish experience" by Gómez-Expósito *et al.*, starts with the review of power system's evolution, from the traditional structure standing on centralized generation and control to supply customers through ac transmission networks and distribution feeders with unidirectional energy flow, to the new structure—the smart grid—in which more renewable generation is deployed by prosumers through dc/ac converters also at the distribution level. Such a new, more complex structure, calls for a use of ICT that is much larger and more widespread with respect to the traditional structure, which is inherently more stable. Recent smart grid projects in Spain, related to smart cities, are then presented. One of them involved virtually all the key technologies that are expected to be applied in future smart cities.

Buildings are certainly the fundamental component of cities, and even though this subject has been already dealt with in a previous special issue of the Proceedings of the IEEE [5], a contribution on this topic could not be missed in this Special Issue. This is represented by the eighth paper, "Data-enabled building energy savings (D-E BES)" by Abrol *et al.*, which illustrates that creating an affinity between a building resident's thermal preferences and a building apartment's unregulated thermal environment represents an alternative means of generating an energy-efficient environment for multifamily, residential buildings.

The ninth paper, "Smart governance for smart cities" by Razaghi and Finger, brings together insights from sociotechnical systems, systems theory, and governance literature to shed light on why city administrations should closely follow these changes and adapt the governance approaches accordingly.

The tenth, eleventh, and twelfth papers show how advanced engineering and ICT can be of fundamental help for solving community health problems. As urban living in modern large cities has significant adverse effects on health, it is of utmost relevance to focus on the possibility that available or potentially available data could help in the action of preventing chronic diseases. Two leading clusters of chronic disease, heart disease and diabetes, are addressed in the first of these three papers, "Predicting chronic disease hospitalizations from electronic health records: An interpretable classification approach" by Brisimi *et al.*, which develops data-driven methods to predict hospitalizations due to these conditions. The second of these papers, "Using smart city technology to make healthcare smarter" by Cook *et al.*, discusses the positive impact that smart city ICT can have on healthcare effectiveness and cost. Smart city infrastructure is shown to be capable of supporting strategic healthcare using both mobile and ambient sensors combined with machine learning. The third of these papers, "Predicting frailty condition in elderly using multidimensional socioclinical databases" by Bertini *et al.*, proposes two different predictive models for frailty by exploiting a number of socioclinical databases. As a matter of fact, in recent decades, life expectancy increased globally, leading to various age-related issues in almost all developed countries; this paper aims to address these issues at least in part.

The last paper, "The need of multidisciplinary approaches and engineering tools for the development and implementation of the smart city paradigm" by Andrisano *et al.*, is a choral contribution by researchers of the University of Bologna, Italy, aimed at further proving the concept that the successful, effective, and sustainable implementation of the smart city paradigm requires a multidisciplinary approach and a strict cooperation among researchers with different, complementary interests. The following subjects are reviewed: joint computing and communication management for smart city applications, sustainable policies, citizens' active participation through mobile crowdsensing, real-time analysis of big data in cybersecurity, sustainable urban mobility, heterogeneous network for smart navigation, E-mobility effect on the smart grid, cosimulation, historic masonry building and environmental actions, monitoring technologies and control systems applied to integrated water service, and a smart and sustainable approach to optimization/renovation of the built environment.

Some relevant results, achieved thanks to some pilot projects carried out within the context of some EU-financed projects run by the authors in cooperation with national and international players, Bologna Municipality and the Regional Technology Network, are eventually presented and discussed.

III. THE SMART CITY: "THE" MULTIDISCIPLINARY PARADIGM

This Special Issue covers only some aspects of smart cities, and this is mainly for two reasons: the limited space available and the fact that the smart city is a real multidisciplinary subject that cannot be dealt with exhaustively in an engineering journal, which is not expected to deal with economics and social sciences. However, we trust that readers will find the papers in this issue valuable and informative. One last remark that we feel is worth adding is as follows: The need for multidisciplinary research cooperation is crucial in many scientific areas, but in the case of smart cities, the multiple nature of a collaboration is not limited to scientific issues, but is extended to the nature and type of the players. Academics with different scientific and humanities background need to cooperate not only with each other and with industrial players more than in any other technical challenge, but they also need to interact and cooperate with local municipality governances and regional communities.

All papers presented show that smart cities are a growing reality, although major steps need to be still accomplished. One of those is standardization, still missing in part. Business models is another one; there will be no sustainable disruption happening without new business models and new game players emerging. Even the cities will have to create their own business model. ■

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ABOUT THE AUTHORS

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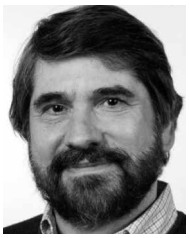

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