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The role of big data in smart city

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ABSTRACT

The expansion of big data and the evolution of Internet of Things (IoT) technologies have played an important role in the feasibility of smart city initiatives. Big data offer the potential for cities to obtain valuable insights from a large amount of data collected through various sources, and the IoT allows the integration of sensors, radio-frequency identification, and Bluetooth in the real-world environment using highly networked services. The combination of the IoT and big data is an unexplored research area that has brought new and interesting challenges for achieving the goal of future smart cities. These new challenges focus primarily on problems related to business and technology that enable cities to actualize the vision, principles, and requirements of the applications of smart cities by realizing the main smart environment characteristics. In this paper, we describe the state-of-the-art communication technologies and smart-based applications used within the context of smart cities. The visions of big data analytics to support smart cities are discussed by focusing on how big data can fundamentally change urban populations at different levels. Moreover, a future business model of big data for smart cities is proposed, and the business and technological research challenges are identified. This study can serve as a benchmark for researchers and industries for the future progress and development of smart cities in the context of big data.

1. Introduction

The paradigm shifts from the realm of traditional desktop computing to an increasingly sophisticated computing (Gubbi, Buyya, Marusic, & Palaniswami, 2013) as well as the significant increase in connected devices and sensors have made feasible the vision for living in a smart environment. Several applications of a smart environment have been introduced recently, including smart homes (Caragliu, Del Bo, & Nijkamp, 2011), smart grids (Chen, Song, Li, & Shen, 2009), smart transportation (Adeli & Jiang, 2009), smart healthcare (Demirkan, 2013), and smart cities (Caragliu et al., 2011; Chourabi et al., 2012), because of the growth of urban population and rapid urbanization. At present, urban performance depends not only on the physical infrastructure but also on the availability and quality of knowledge communication and social infrastructure (Caragliu et al., 2011). The key enabler of these smart city applications is possibly the IoT in which everyday objects and devices are connected to the network technologies.

The promise of a smart city leads to an exponential increase in data by several orders of magnitude. Consequently, such enormous volumes of data or big data are at the core of the services rendered by the IoT. The phenomenon of big data has long been characterized by volume, velocity, and a variety of data types that have been created at ever-increasing rates (Gani, Siddiqa, Shamshirband, & Hanum, 2016; Khan et al., 2014). Big data offers the potential for the city to obtain valuable insights from a considerable amount of data collected through various sources. Certainly, the characteristics of such data mostly include unstructured features compared with big data collected by other means (Chen, Mao, & Liu, 2014). Fig. 1 illustrates the landscape of the smart technologies with big data and cloud computing, in which various smart applications exchange information using embedded sensor devices and other devices integrated with the cloud-computing infrastructure to generate large amounts of unstructured data. These large amounts of unstructured

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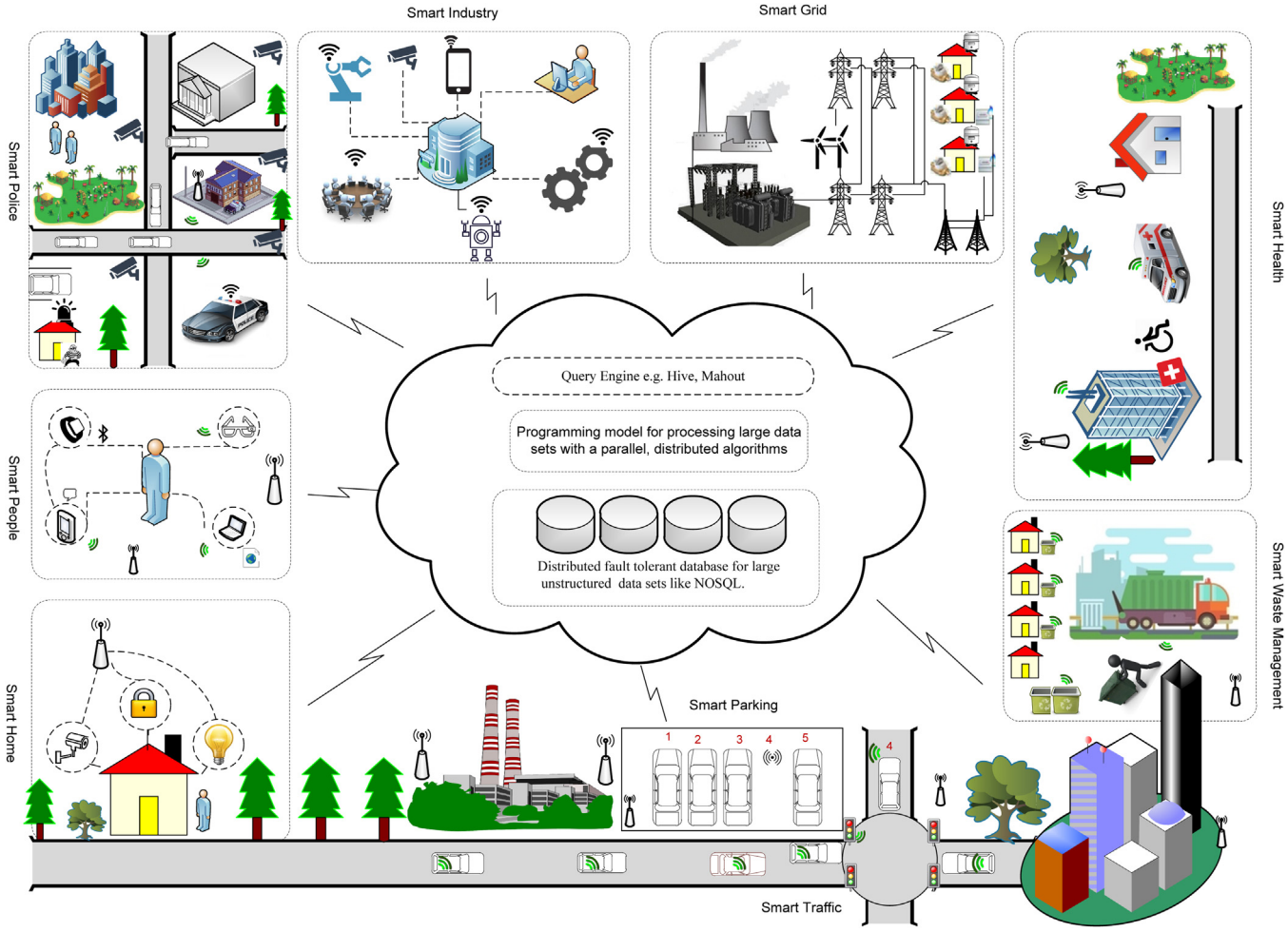

Fig. 1. Landscape of the smart city and big data technologies.

data are collected and stored in the cloud or data center using distributed fault tolerant databases such as Not Only SQL, which is used to improve a single service or application and is shared among various services (Borgia, 2014). Thus, the programming model for processing large data sets with parallel algorithms can be used for data analytics to obtain value from the stored data.

Smart cities have played a key role in transforming different areas of human life, touching sectors such as transportation, health, energy, and education. For example, the data of weather information are significantly increasing at a rapid pace. Identifying and obtaining valuable information from large amounts of weather data can be extremely beneficial in terms of agricultural development. Moreover, analytics of the weather data can help inform the people in advance about the possible hazardous conditions (e.g., flood information, extremely hot weather, drought, and so on) (Fan & Bifet, 2013). Governments have begun to embrace smart city ideas to improve the living standard of their citizens and to implement big data applications (Jimenez, Solanas, & Falcone, 2014). Big data for the smart city can transform every sector of a nation's economy (Batty, 2013). Such transformation enables cities to actualize the learning principles and requirements of the applications of the smart city by realizing the main smart environment characteristics. These characteristics include, among other things, sustainability, resilience, governance, improved quality of life, and intelligent management of natural resources and city facilities (Al Nuaimi, Al Neyadi, Mohamed, & Al-Jaroodi, 2015). The smart city takes advantage of emerging technologies, such as wireless sensor networks (WSN), to reduce cost and resource consumption. However, applying big data analytics in the smart environment remains in its infancy stage. One of the emerging technologies with the huge potential to enhance smart city services is big data analytics (Al Nuaimi et al., 2015). At present, a large amount of data is being generated from different data sources, such as smartphones, computers, sensors, cameras, global positioning systems, social networking sites, commercial transactions, and games. Given that the data generated in our present digitized world continuously grow, efficient data storage and processing facilities have posed challenges to the traditional data mining and analytics platforms. Big data analytics can extract meaningful information from the oceans of data produced by sensor devices (Yaqoob, Chang, Gani, Mokhtar, & Abaker, et al., 2016). Effective analysis and utilization of big data are a key factor for the success in many business and service domains, including the smart city application. The application of big data in a smart city has many benefits and challenges, including the availability of large computational and storage facilities to process streams of data produced within a smart city environment. One of the possible means to tap this benefit is a reliance on cloud computing services and IoT technologies.

The goal of this study is to offer a comprehensive survey of big data in smart cities, more specifically, the role of big data for sustainability and improvement on the living standards in urban cities. Thus, this paper is motivated by two factors. First is the current availability of smart devices that generate large heterogeneous datasets every day. The second factor is the smart applications that