

Chapter 3

Towards a Secure, Distributed, and Reliable Cloud-Based Reference Architecture for Big Data in Smart Cities

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ABSTRACT

Current revolutions with respect to big data affect people's everyday life more and more. New ways of living, communication, and knowledge sharing have been created under the smart city umbrella. Information and communication technologies (ICT) are used to improve urban services. Examples are car sharing, energy consumption, adaptive traffic management, etc. A closer look at these services reveals that data, produced and consumed by people (or automatically by devices), are the cornerstone for working and reliable urban services. For this, large volumes of data with a great variety have to be processed at a high velocity which is commonly known as big data. This chapter designs a secure, distributed, and reliable cloud-based reference architecture that logically separates confidential data and distributes them to various databases in different clouds. It increases the reliability of the distributed data with high-availability mechanisms to protect data against various threats (e.g., hackers, terrorists, data collecting companies, etc.).

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INTRODUCTION

Current revolutions with respect to Big Data, Internet of Things, or Industry 4.0 affect people's everyday life more and more. An example for this is the development of the World Wide Web (WWW 1.0) to the Semantic Web (WWW 3.0). Thus, new ways of how people communicate, interact, and share knowledge with each other have been created. This also holds for recent developments under the *Smart City* umbrella, which subsumes urban development strategies towards a sustainable management of resources like space, traffic, and other infrastructural assets, but also services, e.g. municipal, governmental, health care, or industrial ones (Song, Srinivasan, Sookoor, & Jeschke, 2016) (Dameri & Rosenthal-Sabroux, 2014) (Dey, Hassanien, Bhatt, Ashour, & Satapathy, 2018) (Elhayatmy, Dey, & Ashour, 2018) (Bhatt, Dey, & Ashour, 2017) (Sarwar Kamal, Dey, & Ashour, 2017) (Yang, Wang, Song, Yang, & Patnaik, 2018). Here, new Information and Communication Technologies (ICT) architectures are required to implement and improve *urban services*: concrete examples are car sharing, adaptive traffic management, energy consumption, etc. A general goal for these *urban services* is to reach a high degree of automation (without any human interaction) to increase their efficiency and to reduce costs. A closer look at these services reveals that data, produced and consumed by people (or automatically by their devices) are the cornerstones for working and reliable *urban services*. Therefore, large *volumes* of data with a great *variety* (heterogeneity) have to be processed at a high *velocity* which is commonly known as *Big Data*.

In order to address these *Big Data* challenges, NoSQL databases (in contrast to traditional relational databases) provide appealing architectures (i.e. key-value, column, document stores and graph databases) (Sadalage & Fowler, 2013) (Harrison, 2015), especially when data are processed In-Memory, i.e. not stored and analyzed on hard disk drives (HDD), but in the faster random-access memory (RAM) of a system. These non-relational architectures weaken the hard consistency criteria atomicity, consistency, isolation, and durability (ACID) of relational databases and use the basically available, soft-state, eventual consistency (BASE) model instead. This is advantageous in especially distributed systems, as the strong ACID criteria demand a tremendous synchronization overhead, whereas BASE allows several nodes to be inconsistent for a certain time. However, processing huge amounts of heterogeneous data at great pace requires adequate (and expensive) infrastructure capabilities and this is where Cloud Computing can be taken into consideration.

On the one hand, Cloud Computing promises advantages with its five key characteristics: (1) broad network access, (2) on-demand self-service, (3) rapid elasticity, (4) resource pooling, and (5) measured services (Mell & Grance, 2011). These key characteristics are also essential in a *Smart City* infrastructure, as huge data volumes require a high bandwidth to and from the cloud, especially with a great

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