An Efficient Framework for Smart City Using Big Data Technologies and Internet of Things

Krishna Kumar Mohbey

Abstract The evolution of cloud computing, Internet of things (IoT) and big data has played vital role in the development of smart cities. IoT uses various types of embedded devices, such as sensors, actuators, Bluetooth, Wi-Fi, radio frequency identification (RFID), and ZigBee to collect data from different smart city applications. The huge amount of data, which are collected from different applications are known as big data. To perform real-time processing on data, data collected from smart city applications an efficient framework are required. This framework can combine big data technologies with IoT services toward smart city. In this paper, various IoT communication techniques are discussed with big data technologies. Then, a framework is proposed for handling big data generated from smart city applications. The proposed framework primarily focuses on problems related to smart city vision for real-time decision-making. In addition, this paper discusses the various principles and requirements of smart city for enhancing the life standard of people. The proposed framework can serve as a benchmark for authorities and policy makers in smart cities enhancement with the use of IoT concept, features, and big data technologies.

Keywords Smart city · Internet of things · Big data technologies · Cloud computing

1 Introduction

The concept of smart city includes a modern urban area that enhances the living standard of people through utilizing information technology, effective communication, and proper data management. Smart city development is a concept, which includes physical infrastructure enhancement as well as various factors and strategies related to citizenship and environment. With the enhancement of sophisticated computing

K. K. Mohbey (✉)
Department of Computer Science, Central University of Rajasthan, Ajmer, India
e-mail: kmohbey@gmail.com

C. R. Panigrahi et al. (eds.), *Progress in Advanced Computing and Intelligent Engineering*, Advances in Intelligent Systems and Computing 714,
https://doi.org/10.1007/978-981-13-0224-4_29

Fig. 1 Different applications of smart city

and technology [1], lots of devices are connected through sensors. In today's world, sensor technology and IoT have provided the solution for living in a smart environment, i.e., smart city. To make a city smarter, it is needed to manage environment in an efficient way that is required for natural resources, mobility, governance, transportation, traffic, health care, education, energy, etc. To fulfill these objectives, several services of smart city [2] have been introduced recently, including smart grid [3], smart transportation [4], smart home [5], smart health care [6], smart education, smart energy, and smart mobility [2, 7], and so on. Figure 1 shows the different applications of the smart city.

At present, smart city management mainly depends on the advancement of physical infrastructure and efficient communication for real-time decision-making [5]. The communication between various applications of smart city is possible through IoT. With the IoT technology, various objects of different applications are connected in the proper way to enhance the quality of communication and availability of real-time data.

Due to the rapid increase in the IoT technologies toward smart city applications, data is generating at high volume in every second. This data is generated in the form of high volume, velocity and variety [8, 9]. These collected data are useful for smart city enhancement since it describes the actual value and characteristics of smart city applications. The big data collected from various sources are mostly including unstructured features as compared to data collected by other means [10]. Figure 2 shows the relationship between various smart city applications, big data and cloud computing. This figure also demonstrates the exchange of information between various smart city applications using IoT sensors and cloud platform. This collected big data are unstructured in nature and stored in different data centers using a

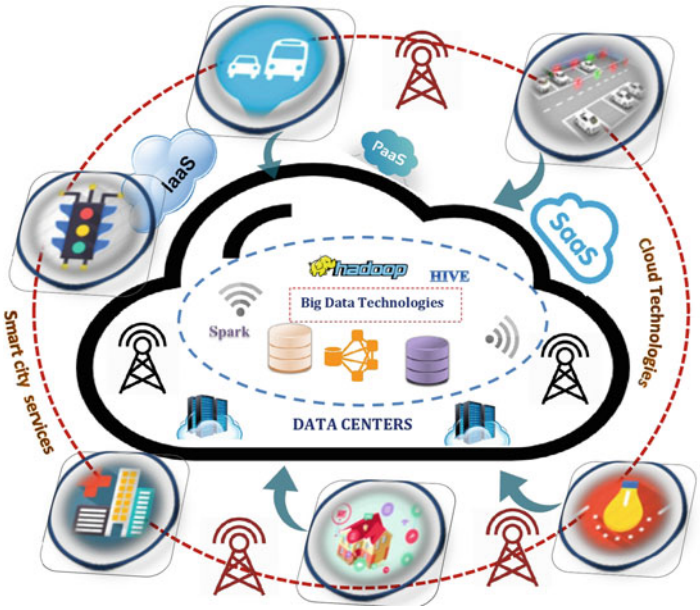

Fig. 2 The relationship between smart city applications, big data, and cloud infrastructure

distributed database such as NoSQL. The purpose of storing data in data center is to share among various applications of smart cities using cloud platform [11]. To process this big data, a programming model is also required with parallel algorithms to obtained valuable results. Smart city has enhanced the living standard of urban citizen through transmitting different areas of human life such as health, home, energy, transport, water, education, governance, pollution, etc. Various governments have already started smart city ideas in their country to fulfill requirements of the citizens [12].

With the development of various technologies toward smart city, applications can transform various sectors of the nations economy [13]. This transformation supports smart cities to collect various requirements for their enhancements. Improving the citizen lifestyle in smart city requires various technologies such as wireless sensor network (WSN), embedded devices, and IoT. In addition, big data analytics is also important for smart city applications [14]. Big data are generated from various sources like mobile phones, cameras, GPS, social media, sensors, computers, and so on. Therefore, efficient data storage and processing have become a challenging task to manage it. Proper management and effective analysis of data are the main tasks for the success of a smart city. One of the possible solutions for big data management is to collaborate cloud services with IoT. This study mainly focuses on conducting a survey of smart city applications with big data technologies toward enhancing the living standard of urban citizens.

2 Related Work

The purpose of smart city is to provide continuous information to make a real-time decision, which would be helpful to the citizens of that city. To develop such kind of smart city, we need to deploy several IoT devices at different places for different services. IoT devices are used to make an intelligent system for smart city which includes home, traffic, transportation, education, etc. [1]. The motivation of smart city is to make an intelligent system in all fields related to citizen. These fields included hospitals, schools, railways, roads, buildings, and the environment and so on [15]. Intelligent system development is possible with the interconnection of various sensors and actuating devices, which can be used for sharing information between different platforms. To develop such kind of smart and intelligent system requires frameworks that include cloud computing and big data technologies [1]. Big data technologies are capable to store, process, and produce information intelligently. Hadoop and MapReduce are the important technologies to handle big data [16].

Due to different kind of services and huge amount of data storing, cloud computing models are required. It provides the facility to connect many devices or clusters at real-time [17]. Cloud computing models are capable to handle complex and large-scale computing tasks [18]. Cloud computing services include platform as a service (PaaS), software as a service (SaaS), and infrastructure as a service (IaaS). Cloud computing also provides different services which can be used to manage data [19].

Real-time data storage and processing are the biggest task in smart city. It also includes streaming architecture and seamless communication between various sensors within the smart city services. A lot of research is going in this direction, but it still requires an efficient framework to enhance the efficiency and processing at real-time environment.

3 IoT Communication Technologies

An effective communication is required to make a city smart. This communication is possible through connecting various equipments to collect real-time data. This equipment includes smart home devices, sensors, smartphones, laptops, etc. The communication should be capable of transferring real-time collected data. In this section, various IoT communication technologies are highlighted, which are beneficial for smart cities.

3.1 WSN

A wireless sensor network (WSN) is used to connect various distributed and independent devices. It works on low power integrated circuits and wireless technology to connect devices. It is capable of monitoring physical as well as environmental conditions in real-time toward smart city services. It can monitor temperature, light, humidity, pressure, etc. In addition, radio transceiver is used in WSN for sending and receiving signals through wireless technology [20].

3.2 RFID

Radio frequency identification (RFID) is a technology which uses electromagnetic coupling in the radio frequency to uniquely identify an object. This technology is useful for smart city applications as well as IoT device communications because it is capable to identify any object. It can be used with any kind of objects such as person, car, animal, cloth, and so on. In addition, to make a city smarter, it can be applied in schools, hospitals, libraries, environments, and other places [7].

3.3 LTE, 4G, and 5G

The long-term evolution (LTE) technology is used to connect various devices with 4G wireless network. It supports hybrid data and voice communication. This technique is an efficient scheme which supports high data transfer. With this technique, multiple users can share a common channel. In addition, 5G supports high bandwidth up to 10 Gbit/s [7].

3.4 Wi-Fi

A smart city is fully connected with wireless communication because it is fast, flexible, and secure. It has various features like low cost, dynamic network improvement, and easy deployment. It is the replacement of the cable network and provides facility to access the Internet at broadband speed [11].

3.5 ZigBee

ZigBee is a wireless communication technology and generally used for short range communication between devices. It is capable for reliable, robust, secure, and low power consumption. In smart city services, it is widely used in a smart home for connecting devices, in smart lighting and in other places [7].

3.6 Bluetooth

Short range communication is possible through Bluetooth which uses wireless radio system. It replaced cable for computer peripherals such as keyboard, mouse, printer, joysticks, and so on. Due to low power consumption, it is useful for communicating various smart city objects [19].

4 The Role of Big Data in Smart City Services

Smart city services produce huge amount of data every day due to real-time data collection. To store, manage, and process, this data required advanced technologies for efficient data processing. Big data technologies provide various tools and methods which are able to collaborate with different services and enhance the smart city standards. These technologies are also capable to analyze data and predict decisions toward smart city enhancement. In this section, some important services of smart city are discussed.

4.1 Smart Home

Smart home is an important service of smart city in which different objects are connected through IoT sensors and controlled by smartphones or other computing devices. Home objects collect data from various sources by sensors, camera, Wi-Fi, Bluetooth, and so on. The collected data transfer to storage unit for further processing [21].

4.2 Smart Health Care

Smart healthcare systems manage health-related e-data. In smart city, various healthcare centers are connected through sensors and IoT devices to provide

communication between hospitals, patients, doctors, and diagnosis machines. It includes online medical services like online appointment, digital record storage, remote home services, alarm system, and remote patient monitoring [6].

4.3 Smart Transportation

The purpose of smart transportation is to minimize traffic congestion. Number of accidents can be reducing by providing alternate routes to vehicles. With the use of various IoT sensors, cameras, smart vehicles and RFID techniques transportation can make effective. This system is capable to predict real-time traffic patterns which are useful for safe and secure traffic [7, 21].

4.4 Smart Grid

This system uses advanced meters, readers, and communication network to understand real-time power demand and consumption. In smart grid, real-time monitoring can be achieved through computer-based remote controls. These controllers used between power producers and consumers to increase efficiency [22].

4.5 Smart Governance

The government can easily analyze various results using big data technologies which are beneficial for citizens of a smart city. Big data techniques can help the government to make policies, implement, and monitor in real-time.

5 Proposed Framework

Smart city services produced data continuously in different formats. Managing such kind of data existing approaches and techniques is not sufficient due to limited processing speed and limited storage capability. To handle this problem, it is needed to develop an efficient framework with the help of big data technologies. The proposed framework is based on parallel processing on distributed data storage. The proposed framework for smart city data processing is shown in Fig. 3.

This framework is divided into multiple layers, where each layer is responsible for a specific task.

The first layer is responsible for communication and data generation. It consists of various objects and IoT embedded devices in smart city. These devices generate

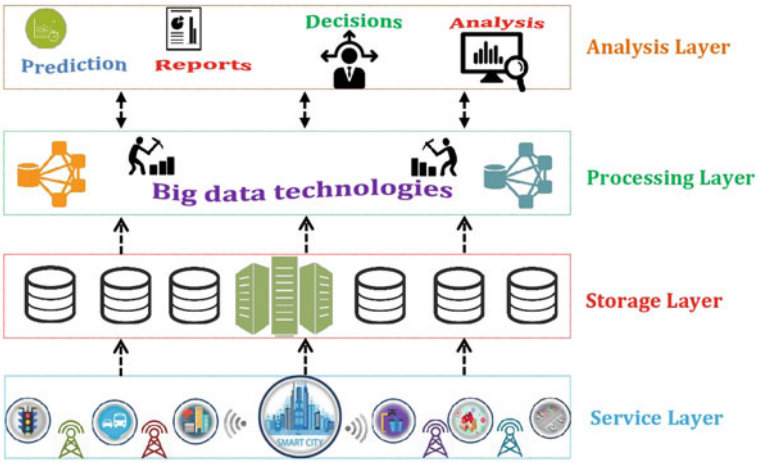

Fig. 3 Framework for smart city data processing using big data technologies

large amounts of heterogeneous data. Second layer is responsible for collecting and storing data in a distributed environment after applying preprocessing. The generated data are stored with the help of big data technologies such as Google cloud, Microsoft Azure, Amazon, and so on. In the third layer, the stored data will processed according to given queries using big data techniques such as MapReduce framework [23]. MapReduce is a high processing model for distributed and parallel processing. It makes various clusters of data for processing. Analysis layer is the last layer, which provides facility to interact people and devices directly to make real-time decisions. The result of analysis may be used for prediction, report generation, and recommendations for smart city.

6 Conclusion

In this paper, an efficient framework for smart city services has been proposed, which will be useful for managing real-time generated data. This large data is continuously generated by the various IoT embedded devices of smart city services. This paper also describes various IoT communication technologies toward smart city services. Finally, this paper concludes that big data and IoT devices are the building blocks of a smart city. The proposed framework is capable for decision-making and policies enhancement which can change the lifestyle of the citizens.

References

1. Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M.: Internet of Things (IoT): a vision, architectural elements, and future directions. Future Generation Computer Systems, 29(7), 1645–1660 (2013).
2. Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J. R., Mellouli, S., Nahon, K., & Scholl, H. J.: Understanding smart cities: an integrative framework. Paper presented at the 45th Hawaii International Conference on System Science (HICSS), (2012).
3. Chen, S.-y., Song, S.-f, Li, L., & Shen, J.: Survey on smart grid technology. Power System Technology, 33(8), 17 (2009).
4. Adeli, H., & Jiang, X.: Intelligent infrastructure: neural networks wavelets, and chaos theory for intelligent transportation systems and smart structures. CRC press, (2009).
5. Caragliu, A., Del Bo, C., & Nijkamp, P.: Smart cities in Europe. Journal of Urban Technology, 18(2), 6582 (2011).
6. Demirkan, H.: A smart healthcare systems framework. It Professional, 15(5), 3845 (2013).
7. Hashem, I. A. T., Chang, V., Anuar, N. B., Adewole, K., Yaqoob, I., Gani, A., & Chiroma, H.: The role of big data in smart city. International Journal of Information Management, 36(5), 748–758 (2016).
8. Gani, A., Siddiqa, A., Shamshirband, S., & Hanum, F.: A survey on indexing techniques for big data: taxonomy and performance evaluation. Knowledge and Information Systems, 46(2), 241–284 (2016).
9. Khan, N., Yaqoob, I., Hashem, I. A. T., Inayat, Z., Mahmoud Ali, W. K., Alam, M., & Gani, A.: Big data: survey, technologies, opportunities, and challenges. The Scientific World Journal, (2014). https://doi.org/10.1155/2014/712826.
10. Chen, M., Mao, S., & Liu, Y.: Big data: a survey. Mobile Networks and Applications, 19(2), 171–209 (2014).
11. Borgia, E.: The internet of things vision: key features, applications and open issues. Computer Communications, 54, 131 (2014).
12. Jimenez, C. E., Solanas, A., & Falcone, F.: E-government interoperability: linking open and smart government. Computer, 47(10), 22–24 (2014).
13. Batty, M.: Big data, smart cities and city planning. Dialogues in Human Geography, 3(3), 274–279 (2013).
14. Al Nuaimi, E., Al Neyadi, H., Mohamed, N., & Al-Jaroodi, J.: Applications of big data to smart cities. Journal of Internet Services and Applications, 6(1), 115 (2015).
15. Su, K., Li, J., & Fu, H.: Smart city and the applications. Paper presented at the 2011 International Conference on Electronics, Communications and Control (ICECC) (2011).
16. Hashem, I. A. T., Anuar, N. B., Gani, A., Yaqoob, I., Xia, F., & Khan, S. U.: MapReduce: review and open challenges. Scientometrics, 134 (2016). https://doi.org/10.1007/s11192-016-1945-y.
17. Mell, P., & Grance, T.: The NIST definition of cloud computing (2011).
18. Chang, V., Bacigalupo, D., Wills, G., & Roure, D. D.: A categorisation of cloud computing business models. Paper presented at the Proceedings of the 2010, 10th IEEE/ACM International Conference on Cluster, Cloud and Grid Computing (2010).
19. Hashem, I. A. T., Yaqoob, I., Anuar, N. B., Mokhtar, S., Gani, A., & Khan, S. U.: The rise of big data on cloud computing: review and open research issues. Information Systems, 47, 98115 (2015). https://doi.org/10.1016/j.is.2014.07.006.
20. Dargie, W. W., & Poellabauer, C.: Fundamentals of wireless sensor networks: theory and practice. John Wiley & Sons (2010).

21. Mohbey, K.K.: The role of big data, cloud computing and IoT to make cities smarter, Int. J. Society Systems Science, Vol. 9, No. 1, pp. 75–88 (2017).
22. Lai, C. S., & McCulloch, M. D.: Big data analytics for smart grid. (2015). Retrieved from Accessed 23. 04. 16. http://smartgrid.ieee.org/newsletters/october-2015/big-data-analyticsfor-smart-grid.
23. Dean, J., & Ghemawat, S.: MapReduce: simplified data processing on large clusters. Communications of the ACM, 51(1), 107–113 (2008).