Chapter 12
Internet of Things–Based Smart City Environments Using Big Data Analytics: A Survey

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Abstract The intense growth and acceptance of the Internet of Things (IoT) is reflected in the trend of smart cities. Smart cities are being implemented to improve standards of living and provide higher-quality services to residents. These services may include (but are not limited to) parking, water, health, transportation, environment, and power. The varied implementations of smart cities and the IoT are challenged by the processing of gigantic data and real-time decision management. In this chapter, we explore the use of big data analytics in IoT-based smart city development and design. This chapter provides a conceptual framework for the use of big data analytics in IoT-based smart city environments.

12.1 Internet of Things

British technology pioneer Kevin Ashton first used the term "Internet of Things" (IoT) in 1999. The IoT is a system in which different devices, actuators, and sensors [1, 2] are connected by our physical world. The internet acts as a bridge between the real world and different devices for communication. Iot plays a vital role in the development of smart cities environment [3]. Equally, the cloud-based and scalable video coding is also is the key parameters for setting-up the smart environment [4].

The IoT is a new frontier for researchers. It provides computing ability and internet connections in a variety of everyday objects, sensors, and devices. The wide application of IoT has the potential to change our lives. IoT can be used for industrial applications, water management, smart traffic controls, and noise sensing in our environment. For the consumer, new IoT trends offer different services to use in home appliances, automate home objects by remote access, and manage energy

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in secure and efficient system smart home systems. The IoT also can be used in wearable products to monitor health through different functions installed in mobile applications. The IoT can provide users with independence and quality of life in a cost-effective manner.

A large number of organizations are expected to offer IoT applications in different domains over the next 10 years. For example, according to Cisco, almost 24 billion objects will be connecting via the internet by 2019 [5]. Morgan Stanley projected that 75 billion different network devices will be connected in 2020 [6]. Huawei predicted that 100 million different devices will be connecting to the IoT by 2025 [7]. Finally, McKinsey Global forecasted a revenue gain of $3.9 to $11.1 trillion by 2025 for IoT equipment.

Even though the IoT is considered to be a new trend, the concept of using different devices, computers, and networks to monitor and control objects has existed for many years. For example, in the 1970s, commercial telephone line monitoring meters were operated remotely on the electrical grid. In the 1990s, an industrial solution for machine-to-machine IP-based wireless connectivity was proposed for monitoring and operating a variety of devices [8]. The IoT is a new approach for research into smart object networking. From a broad viewpoint, it is now possible to interconnect increasingly smaller and more numerous devices inexpensively and effectively through "smart object networking." According to the Internet Architecture Board [9–14], smart objects are defined as a large number of embedded devices connected via internet protocols that communicate with each other and offer services. Many of these devices have no need for human intervention. Instead, they extract the information from their environment, such as a building or vehicle.

Smart objects have different non-functional requirements, such as limited power, memory and processing resources, and bandwidth. The main requirement is interoperability between different devices. In the IoT, four basic communication models are is used for small device design strategy to permit communication with each other: device-to-device communication, device-to-cloud communication, the device-to-gateway model, and the back-end data-sharing model. A variety of concerns are also associated with the IoT, including security, privacy, interoperability, standards, economic development, and legal regulations.

12.1.1 IoT Applications

IoT applications can deployed for smart cities, smart homes, wearable devices, smart grids, industrial internet, connected automobiles, smart farming, smart traffic, health applications, retail, security, energy, water management, waste management, noise management, and pollution management.

12.1.2 Importance of IoT

IoT generally provides a high level of knowledge about the environment by continuously monitoring and providing information about it. The IoT can provide new services for society, allowing many fields to be managed with less effort and less time. The IoT is a new industrial revolution in the lives of common people. This innovation has changed the communication between people and devices, improving standards of living and making daily life easier.

12.1.3 Challenges of IoT

Several major challenges are facing the IoT, as follows:

Big Data Expansion IoT devices obtain different types of data from various sources. The large volume of data is a big challenge to address in IoT as applications expand.

Power Efficiency IoT devices have sensors and switches connected through power, so it is a big challenge to supply power to all connected devices over the internet.

Security The IoT also has associated security issues. Companies have a responsibility to address concerns about information vulnerability, particularly when a product is used daily by a consumer. IoT manufacturers should ensure that their devices are secure from cyberattacks and that the data are protected from access by any unauthorized person.

Privacy IoT data are collected by different sources, such as sensors and actuators, and shared with other devices. Therefore, privacy is big challenge in this context. Personal information should be safe and not shared without permission.

Interoperability/Standards Interoperability is not possible in every environment. Therefore, when a user cannot adopt IoT services with confidence, they hesitate to buy IoT services or products because of their high cost, inflexibility, and high ownership complexity. In this regard, different standard models and strategies have been proposed and implemented.

Legal Regulations and Rights The IoT is an emergent field. New technology always introduces new issues regarding laws and regulations, as well as internet-related administrative rules. Various problems can arise when different devices are interoperating with each other, transferring and receiving data over the internet. From a user perspective, it is important that information transmitted over the internet be secured from hackers and abusers. Therefore, we cannot ignore security and legal rights when adopting IOT services.

Emerging Economic and Development Issues The IoT encompasses all areas of life and promises secure social and economy lives for everyone in the future. By

2050, it is expected that several smart cities will be established, which increases the need for cost- and time-effective security. Smart cities may include transportation management, water management, sustainability, healthcare, mobility, and smart parking, among others.

12.2 Smart Cities

The smart city is a small, urban area that incorporates a variety of information technology in a modern way to manage different domains, such as schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement, and other community services. The purpose of the smart city is to enhance the standards of living through information technology and to offer better services within the smart city. The purpose of the information communication technology is to monitor and sense any event that occurs within a smart city. Sensors are deployed in a smart city to obtain information from the environment, thus improving the residential quality of life and saving residents both time and money.

The deployment of the IoT in an urban area in a specific domain that follows government rules and utilizes an information communication technology solution to manage residential community problems is called a *smart city* [15]. The criteria for the selection of a smart city in the very initial stages of government of India include adoption of selection criteria within the budget.

12.2.1 Why Cities Need to Become Smart

Adequate fresh water, general access to cleaner living, the capacity to travel efficiently, a feeling of well-being and security—these are some of the issues that present-day urban communities must satisfy to remain aggressive and provide personal satisfaction to their residents [11]. By 2050, 66% of the world's population is expected to have shifted to cities. Then, problems with standards of living and quality of life will arise. To address these concerns, smart cities will be established in the future.

12.2.2 Smart Traffic: Smart City Applications

Europe has encouraged many countries to adopt smart city technology for traffic management. The European Commission allocated 365 million Euros to member nations for this purpose. Paris has already benefitted from this technology by establishing an electric car smart city, called Autoli. Almost 3000 vehicles are connected by GPS to help drivers find reserved parking. London also started a

smart city many years ago so that drives could quickly access parking. The United Kingdom has deployed smart electric car and bike sharing programs. Furthermore, Copenhagen and New York have establish smart cities for traffic management.

12.2.3 Healthcare: Smart City Applications

The most important and attractive areas for IoT applications are medicine and healthcare. The IoT plays an important role in the medical field in different contexts. IoT medical applications can remotely obtain information on different diseases and recommend medications online. For this purpose, medical diagnostic equipment may be deployed in smart devices to continue monitoring patients. The IoT paradigm improves patient health and quality of life, as well as reduces costs. All patient data is stored in a central repository or cloud server. Whenever required, any health-related data can be accessed by the doctor or patient from the repository. The core idea is to collect scattered and disparate data from different sources and apply useful strategies for examining and changing raw data into useful datasets [16].

The application of big data in healthcare is not an easy task. It requires expert team members, competent vendors, and thoughtful techniques. Different challenges occur daily with the expanding use of the IoT. Different devices and connections provide patient information in different formats, so expert team members are needed to overcome this issue. Waste and abuse also play important roles in healthcare fraud that increase the economic costs. However, big data analytics can limit healthcare fraud by using different prediction techniques.

12.3 Big Data Analytics

In big data analytics, massive datasets can be analyzed in various forms, such as structure/unstructured, batch/streaming, and different sizes (zettabytes and terabytes). Big data is used where traditional systems lack the ability to process and manage the data.

12.3.1 Importance of Big Data

Big data can help companies understand customer needs, reduce costs, detect risks, monitor for fraud, make processes more efficient, facilitate faster and better decision-making, and offer new product and services. When big data is successfully and proficiently captured and prepared, a full understanding of businesses, customers, products, and competitors can result in efficient utilization, lower costs, higher performance, and increased sales. Analyzing large sets of data allows

business users, analysts, and researchers to make faster decisions on data that are not possible in traditional systems.

12.3.2 Characteristics of Big Data

Big data is popular because it allows high-volume, high-velocity, and high-variety data to be managed in an efficient manner. Data come from different sources, so it is necessary to organize raw data into meaningful forms. Various analytic techniques are used for this purpose, such as machine learning, predictive analytics, data mining, and statistics [17]. The "V"s of big data are further explained below:

The Volume In big data, a huge amount of information is involved. Data grows day by day and contains all types and sizes of information (e.g. kilobyte, megabyte, petabyte, terabyte).

The Velocity Data originate at very high speeds, so big data analytics is time sensitive.

The Variety Data are kept in different file formats and types, which are extremely heterogeneous. The data may include structured or unstructured data, such as audio, log files, or video files.

The Value Value addresses the requirement for the evaluation of data and has great importance for information technology infrastructure systems and other businesses to store a variety of values in a database.

The Veracity The increase in the choices of values represents a large data set. Unnecessary or obsolete data that are not correct should undergo further analysis.

12.3.3 Big Data Life Cycle

In this section the steps involved in the life cycle of Big Data analytics are highlighted which are different from the set of activities involved in tradition life cycle model due to high volume, velocity and variety of dataset. It is advance technique that is utilized to bring the large data in meaningful and compact form. Life cycle of Big Data comprised of nine phases which are given below:

1. Business case evaluation
2. Data identification
3. Data acquisition and filtering
4. Data extraction
5. Data validation and cleansing
6. Data aggregation and representation
7. Data analysis
8. Data visualization
9. Utilization of analysis results

12.3.4 Future Opportunities for Big Data

Big data can uncover the concealed behavior of individuals and even shed light on their future plans. More specifically, it can cross over any barrier between what individuals need to do and what they really do, in addition to how they connect with others and their conditions. These data are helpful to government offices and privately owned businesses to help basic leadership in fields ranging from law enforcement to social administration to national security. Big data will change how we live in both minor and substantial ways [15, 18–23].

12.3.5 Challenges of Big Data Analytics

The following are the major challenges faced in big data:

Big Data Format Conversion As discussed previously, there are a diversity of data sources in big data. Therefore, data heterogeneity can limits the effectiveness of data format conversion. The applications used can create more value if such format conversions can be made more effective.

Big Data Allocation Big data allocation includes data generation, acquisition, transmission, storage, and other data transformations in a specific domain [15]. Improving the transfer productivity of big data is a main factor in increasing big data computing.

Big Data Privacy Personal and private data may be leaked through storage, broadcast, and practice, even if the permission of workers is obtained.

12.3.6 Relationship Between IoT and Big Data

In the IoT paradigm, a large number of network sensors are embedded in different types of devices and machines. These sensors are deployed in numerous fields, which further gather data from various categories, such as environmental data, geographical data, and logistic data. There is a dire need for big data adoption in different IoT applications, as the development of big data is already lagging behind [15]. These two technologies are interdependent and should be working together. The extensive deployment of IoT drives and the evolution of data, both in size and type, can provide an opportunity for the application and improvement of big data. Furthermore, the application of big data technology to IoT also speeds up the research improvements and business representations of IoT.

12.3.7 Techniques

Big data requires exceptional strategies to effectively handle huge volumes of information inside constrained run times. Big data techniques involve a number of disciplines, including statistics, data mining, machine learning, neural networks, social network analysis, signal processing, pattern recognition optimization methods, and visualization approaches. Some of the most widely used approaches for big data analytics include Yarn, Map Reduce, Spark, HBase, Hive, Kafka, and Pig.

12.4 Role of IoT and Big Data in Smart Cities

There is only one way for any city to truly become a smart city—through data and analytics. The growth of big data and the advancement of IoT technologies have played a vital role in the feasibility of smart city initiatives [8]. Big data offer the potential for urban areas to obtain significant bits of knowledge from great volumes of information gathered through different sources, and the IoT allows the incorporation of different sensors in different devices using networked services. Companies are providing IoT and big data solutions for everyday operations in order to bring cities into a new era.

The IoT is fundamental when building a smart city. For a city to be entirely "smart," the devices connected to it must be able to communicate with one another. Here, IoT plays a part by providing a perfect template for device communication, hence providing smart solutions for different problems. According to Schuller, everything becomes an opportunity from a smart city perspective [11]. With more than 50% of people now living in urban areas, it is crucial for cities to think about how they can mitigate problems that arise from urbanization.

When IoT technology comes together with big data, cities can be recognized as upcoming smart cities [24, 25]. These smart cities can change the professional and personal lives of their residents on many levels, such as lowering pollution, managing waste, improving parking facility, and increasing energy savings. One of the biggest perks of creating smart cities is that resource waste will be reduced to a very large extent. Decreases in water wastage, congested streets, energy/power consumption, and pollution, among others, will certainly be a boon for the residents living in these smart cities. In fact, several smart cities around the world have already successfully tackled problems such as sewage treatment, water theft, pollution, and traffic congestion over time. Therefore, the combination of IoT technology and big data can help us to achieve the impossible.

12.5 Conclusion

The idea of the smart city is still very novel due to the revolution in conventional city functions. The smart city concept has motivated researchers and industries to construct well-organized and generic architecture. In this chapter, the use of big data analytics in the development and design of IoT-based smart cities was explored. A conceptual framework for the use of big data analytics in IoT-based smart city environments was provided.

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