Chapter 14
Machine Learning, Data Mining, and Big Data Analytics for 5G-Enabled IoT

Puneet Kumar Aggarwal, Parita Jain, Jaya Mehta, Riya Garg, Kshirja Makar, and Poorvi Chaudhary

1 Introduction

The evolving of fifth era (5G) networks is turning out to be all the more promptly available as a significant driver of the development of Internet of Things (IoT) applications. Agreeing to the International Data Corporation (IDC) report, the worldwide 5G administrations will drive 70% of organizations to burn through $1.2 billion on the network the management arrangements. For the new applications and models in the future, IoT require new execution rules such as huge network, security, dependability, inclusion of remote correspondence, super-low latency, throughput, super-reliability, etc. for a colossal number of IoT gadgets. To meet these necessities, the developing Long-Term Evolution (LTE) and 5G innovations are relied upon to give new availability interfaces to the future IoT applications. The advancement of up and coming age of "5G" is at its beginning phase, which focuses on new radio access innovation (RAT), reception apparatus upgrades, utilization of higher frequencies, and re-architecting of the networks. Nonetheless, principal advances have been made, and the development of LTE should be supplemented with an extreme change in the following years in the essentials of remote networking – a generational move in innovation, structures, and business measures. Wireless technology has seen rapid growth in recent years. 4G/LTE is one of the most successful mobile communication networks. It is created in such a way that it is

P. K. Aggarwal (✉)
ABES Engineering College, Ghaziabad, Uttar Pradesh, India

P. Jain
KIET Group of Institutions, Ghaziabad, Uttar Pradesh, India

J. Mehta · R. Garg · K. Makar · P. Chaudhary
HMRITM, Delhi, India

S. Tanwar (ed.), *Blockchain for 5G-Enabled IoT*,
https://doi.org/10.1007/978-3-030-67490-8_14

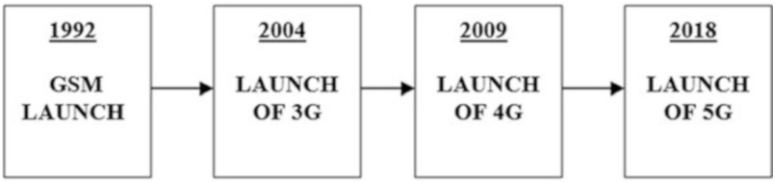

Fig. 14.1 Evolutions of 5G technologies

capable enough to fulfill some of the most critical 5G requirements. The evolution of 5G technology can be seen in Fig. 14.1.

The IoT worldview is both progressive and an empowering influencer of robotized and advantageous ways of life for advanced people. The development of the IoT can be credited to a conversion in progresses that took place over the previous decade in correspondence, computing, and designing applications. The subsequent influence of IoT has extended quickly to cover the entire human race. IoT gadgets are used to encourage human's everyday exercises which incorporates the PDAs, home assistants, smart brilliant vehicles, building computerization frameworks involving smart lifts and temperature control frameworks. Furthermore, automated airborne vehicles, for example, drones for ecological observing and relaxation are also used as IoT gadgets.

The huge scope multiplication of IoT gadgets stretch past these gadgets to the storage centers, for example, backend cloud frameworks which are topographically scattered. Thus, a huge volume of information is created by IoT gadgets and their supporting stages, for move and ensuing storage and preparing at backend distributed storage communities. IoT gadgets produce a steady stream of crude information, which can't be perceived for important information except if the information is prepared through utilization of strategies, for example, information discovery, that is, through data mining and machine intelligence. The heterogeneity of the information produced from different IoT organizations is reliant on the application space, involving smart medical care, online media, e-agribusiness, e-wellbeing, savvy power lattices, and shrewd vehicles. IoT gadgets are planned with custom conventions that consider the asset obliged nature of these gadgets, so as to save power utilization related with gadget activities.

IoT gadgets produce a huge volume of information that is privately prepared, in a restricted way, and also moved to a concentrated processing hub or a cloud storage, where it tends to be additionally prepared or dissected to create information. Machine learning (ML) is characterized as a group of methods for dissecting information, wherein the cycle of model structure on preparing information is mechanized, i.e., expects almost no human mediation. Thusly, the way toward classifying information into different classes is completely mechanized. The function of big data analytics in IoT information handling can't be downplayed. It allows information extraction with the help of ML algorithms. Machine learning algorithms provides an extremely solid support in speedy preparing of enormous

volume information rising up out of IoT gadgets, which helps in creating patterns that is important from analytics point of view [24].

1.1 Research Contributions

The existing 4G networks have been broadly utilized in the IoT and are constantly developing to coordinate the necessities of things to come in future IoT applications. The 5G networks are relied upon to monstrous extend the present IoT that can support cell operations, IoT security, and network difficulties and driving the Internet future to the edge. The current IoT arrangements are confronting various difficulties, for example, huge number of connection of hubs, security, managing data, extracting knowledge, performing data analytics, and new standards for the 5G-enabled IoT. The 5G-empowered IoT (5G IoT) will interface monstrous number of IoT gadgets and make commitments to satisfy market need for remote administrations to invigorate new monetary and social improvement. The new necessities of applications later on IoT and the advancing of 5G remote innovation are two huge patterns that are driving the 5G-empowered IoT. The convergence of big data, data management, IoT platforms, and machine intelligence is empowering the next advancement of data analytics wherein venture will acknowledge critical substantial and elusive advantages from IoT information.

This chapter surveys the current research state of the art of 5G IoT; key empowering technologies including ML, data mining, and big data analytics; and primary exploration patterns and difficulties in 5G IoT.

1.2 Motivation for the Chapter

Presently, various IoT gadgets exploit networks, for example, the third era (3G) and 4G LTE, to keep up their network and their association with the cloud server centers. With the exponential development of information delivered by progressively enormous quantities of IoT gadgets, a few of the serious issues remain unsolved in application development. The 5G communication framework has been presented with the abilities of high-throughput, low-latency, and high unwavering quality. These capacities can empower countless gadgets, with best quality of service (QOS) arrangement of omnipresent network solutions for satisfying their various IoT application necessities. 5G can possibly permit the arrangement of more web-associated gadgets without worry that current issues would be exacerbated by a packed network. The rapid and dependable network supported by 5G will make additional opportunities for IoT services far beyond those accessible today.

Moreover, the empowering advancements of 5G can possibly introduce another IoT era, planning to easily and deftly uphold heterogeneous IoT applications with particular business qualities under countless smart gadgets. Also, the 5G-

enabled IoT will bring a rich wellspring of enormous information. The amazing part of enormous information examination in 5G will without a doubt profit IoT progression.

However, how the empowering advances in 5G whether coordinated into the entire or as an aspect of a framework can consistently fuel the IoT unrest is a challenge. This raises new contemplations of network plan, asset arrangement, the board, nature of involvement, and guideline of 5G-enabled IoT. It is, hence, a basic significance to devise novel solutions by planning keen 5G-empowered IoT ideal models incorporated with the empowering advances of 5G. The IoT has been set up as another cross order research subject requiring the expectation of the specialized and reasonable difficulties looked by blended researchers considering that cross different disciplines.

1.3 Organization of the Chapter

The rest of the chapter is organized into different sections. Section 2 discusses about the concept of data mining and how it is useful for discovering information and hidden patterns from large data sets. In Sect. 3, the concept of machine learning is explored to understand how it will support IoT devices to operate in a better manner, creating a pleasanter lifestyle for society. Then in Sect. 4, big data analytics is explained to understand how the variety of data collected gets gathered, stored, and processed. In Sect. 5, the convergence of data mining, machine learning, and big data analytics gets done, and how it helps in 5G IoT is explained. In Sect. 6, two case studies based on this convergence are explained to understand actually how all the technologies are an advantage to the society. Then in Sect. 7, conclusions are drawn from the chapter. Finally, references are at the last.

2 Data Mining

Data mining (DM) is a process of taking out useful information from a large raw data set which in turn affects the decision-making process [10]. It is employed for the discovery of new information and patterns hidden inside that large data set by including the use of the intersection of artificial intelligence (AI), ML, and statistical analysis as shown in Fig. 14.2. It is considered as a field which is a combined form of computer science and statistics with the basic aim of extracting information and representing it adequately for further use [11].

It also involves a database, data pre-processing, models, complexity, post-processing structures, and online updating. In a nutshell, data mining is the process of digging through a large number of data sets by using different levels of human rules and algorithms to extract hidden information and obtain unique and helpful future outcomes as well. This process of searching includes discovering of

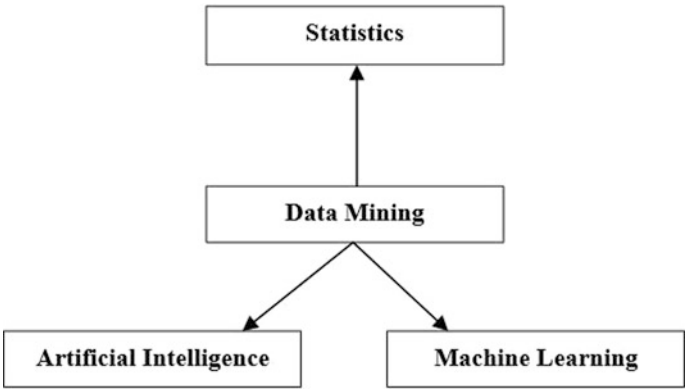

Fig. 14.2 Data mining using AI and ML

aberrations, different kinds of patterns, and relationships among the data which can be further used in different ways. The aim of any data mining procedure is mainly to prepare efficient as well as effective prediction models that even generalize the data. The process of data mining mainly consists of five stages:

Stage 1: Data Collection and Data Loading. This is the first step in the process of data mining where necessary and useful data is collected and loaded in a data warehouse.

Stage 2: Data Storage and Data Administration. After the data collection process, now comes the next important stage, i.e., data storage and its efficient management. The information is mainly stored on the servers or by using the cloud servers.

Stage 3: Information Association. This is the stage where the role of business annotators, administrative teams, and information technology sector comes into play. They have complete access to the data and provide an efficient as well as an effective way to organize a large amount of data.

Stage 4: Data Sorting. Data sorting is performed by the application software based on user results.

Stage 5: Data Representation. In this step, the data is presented in the most user-friendly manner that is easy to read and gather information in less time by the end-user by involving various charts, graphs, or tables. The data mining process further breaks down to mainly three models which are as follows:

(i) Definitive Modeling: It discloses all the similarities and bunches of already existing historical data to understand the antecedents behind success or failure, for example, distinguishing clients by product choices or sentiment.

(ii) Predictive Modeling: It mainly focuses on the classification of the events that will happen shortly, for example, client churn and campaign demand and response.

(iii) Prescriptive Modeling: This modeling deals with internal and external variables and restrictions to study further the course of action, for example, marketing offer to the client.

Information extraction offers the way to deal with a wide measure of machine created and regularly unstructured information. In this manner, huge information innovations and prescient examination permit smoothing out of industrial processes. In this way, the combination of the two sees that there is an upgrade in choice making which is the sole motivation behind both unstructured information and IoT advances. Current studies explore how information mining can take care of information on control and the executive modules.

2.1 Data Mining in 5G-Enabled IoT

Currently, DM is viewed as one of the basic elements for the up and coming age of versatile networks. Through exploration and information investigation, there are desires that multifaceted nature of these networks will be survived and it will be conceivable to do dynamic administration and activity exercises. In order to fully grasp the specifics of 5G network, there are particular sort of data that ought to be assembled by network segments so as to be investigated by an information mining plan. Versatile networks are now essential for our everyday lives; however, what we anticipate from them is ever-evolving. Changing the present networks to 5G is vital to staying up with the requests of a developing network society, where openings range new high-data transmission applications, low inactivity IoT administrations, and beyond. 5G means to fulfill these advancing needs by giving pervasive network for any gadget or application that may profit.

DM is used to extract the hidden information from the data generated. Since IoT promises to provide the caliber in various sectors such as smart cities for the waste management or efficient traffic control or smart homes for monitoring of people or collection of data through the sensors, therefore different data require different analysis techniques [12, 15, 16]. Data mining technique handles not only various manifolds of IoT data and data in bulk but also the speed at which the information is produced. Data mining for the IoT brings certain advantages with some challenges as well which are explained as follows:

(i) *Data admittance and extraction from different locations:* When dealing with the data which is in bulk, having a lot of noise is itself a challenging issue, but detecting a fault and correction is even more difficult. Modification of the data mining algorithm in big data is a tough task.
(ii) *Mining of partial data:* The second challenge is all about mining uncertain data for large data applications. For this, data effectiveness and data security is the most important aspect which needs to be taken into consideration while

transferring the information from various applications such as medical records or transaction records.

In a nutshell, the IoT turns out to rise from the need to automate, investigate, and cope with all the appliances, instruments, and sensors. To frame decisions effectively, IoT and data mining technologies are integrated. This integration supports the optimization of the system.

In the recent years, it has been seen an enormous exertion placed over the span of planning the fifth generation of versatile networks (5G). The development of 5G networks has been pointed toward giving tailor-cut answer for various types of businesses especially the intelligent industries, telecommunication sectors, and wellbeing part and even in smart production lines. On the other hand, the logical network has understood that huge information arrangements can essentially improve the activity and the executives of both current and future portable networks. Normally, DM is utilized throughout finding examples and connections between various factors especially in huge informational indexes. Using factual investigation, AI and ML are utilized in the information set throughout separating essential information from the inspected information.

Data mining is considered to be the most important and valuable aspect for the future generation of networking in mobile. It has proved to be an integral part of 5G technology as it facilitates the process of framing decisions. 5G has helped in evolving many industries mainly the telecommunication sector, transportation industries, and health sector and in smart factories as well [12–14]. Moreover, the big data and predictive analysis have made it even simpler for the execution of these industrial processes. Therefore, the sole purpose of the integration of the two is fulfilled as it provides an effective and enhanced level of decision-making.

It has not only helped in overcoming the complexity issues in networking; rather, it provides a solution to carry out operational activities as well as robust administration. Moreover, the world is alchemizing at a much faster pace and so do the demands and expectations in terms of the mobile network as well. Therefore, the transformation of today's network to 5G is the need of the hour. It adds a great advantage to the existing network such as improving the properties like that of high bandwidth application, less inactive state IoT services, and many more by providing common connectivity. It has been analyzed that nearly 6 years from now, there will be nearly a 34 percent hike in revenues.

Recent research and studies have an entire knowledge and analysis of the fact regarding how data mining handles the control and management techniques. However, along with the success, there come challenges that need to be taken into consideration. The only focus of the research is based on the study of the data mining algorithm to make the best use of it in mobile networking and communication and not on explaining detailed information and examples of the data to be gathered. Also, the number of times of data collection and the various mechanisms of data minimization that need to be exchanged among the network are unknown.

2.2 Applications of Data Mining

Various applications of data mining include [10–12]:

(i) *Descriptive Modeling:* It discloses all the similarities and bunches of already existing historical data to understand the antecedents behind success or failure, for example, distinguishing clients by product choices or sentiment.

(ii) *Banking:* The need for generating, capturing, storing, and transforming data into a useful piece of information has encouraged the industry to use data mining. It acts as a strategy tool for the banks to use it effectively by generating and utilizing the technology for the benefit of the bank. Data mining not only enhances the customer benefit but also used in accessing information. It also helps in finding of the frauds, know about the payment defaults, and market risks as well while doing the different analysis in business. Data mining overall enriches the business processes in the banking industry.

(iii) *Manufacturing:* Data mining is used in the manufacturing field as well. To predict the process of production, error spotting, the quality of the product produced in manufacturing, damage of production assets, and the maintenance of the production, the role of data mining comes into play. There are five major domains in manufacturing where data mining can be used:

   (a) Product design
   (b) Route time evaluation
   (c) Quality
   (d) Delivering system management
   (e) Manufacturing environment

(iv) *Communication:* Data mining is considered one of the most important building blocks of next-generation mobile networks. With the massive increase in telecommunication and multimedia field, a large amount of data is generated such as call details network data or client information. Therefore, data mining can be used to extract and gather a useful piece of information that will benefit the telecommunication industry by predicting the client's experience. It also helps in identifying the frauds, enriching marketing strategies, and gathering prior knowledge of the network faults.

(v) *Beamforming:* It is a traffic-flagging framework for cell base stations that recognizes the most effective information conveyance course to a specific client, and it diminishes impedance for close by clients all the while. Contingent upon the circumstance and the innovation, there are a few different ways for 5G organizations to execute it.

All in all, it is certain that the use of DM in 5G-empowered IoT will see the cell network advancements changed into proactive instead of receptive networks. A portion of the areas that will profit by this reconciliation contain the nature of network load, profile of supporters, accounting data, and design of flaw signs among others.

3 Concept of Machine Learning

Machine learning can be referred to as a subcategory of the AI field, the main aim of which is to focus on examining and recognizing patterns and arrangements in data to facilitate features such as training, thinking, decision-making, learning, and researching without interference from human synergy. Machine learning allows the user to apply a computer algorithm on an enormous sum of data in order to examine and analyze the data and to make recommendations based on that data. If some features require improvement, they are recognized and incorporated for a better design for the future. Machine learning utilizes computational algorithms to do core work for making decisions [1]. Also, the variables, features, and innovations are responsible for making decisions. Core awareness toward the answer is required for the better learning of the embedded system which enables the system to learn.

Actually, the design feeds the machine with data for which the result is already known. The algorithm then runs, and changes are made until the output matches with our result. Increasing volumes of data are fed to boost the system to acquire more eminent decisions. The most important component of the business world is data. Decisions that are derived based on data make the difference in this fast-growing society. Machine learning can be considered as the key to the evolution of data interpretation and formulating decisions for better services.

3.1 Types of Machine Learning

Machine learning can be categorized mainly in three major categories [2]:

(i) *Supervised Machine Learning:* This enables the collected data or composes a knowledgeable output from a former ML progress. It also, managed training as it provides the program with the capacity to attain human-like intelligence. In supervised learning tasks, one provides the program or the machine with a huge set of inputs to attain a fruitful result.

(ii) *Unsupervised Machine Learning:* It aids by getting all sorts of hidden designs in data. In this module, the algorithms attempt to acquire any crucial method of the data with unlabeled samples only. The job is to combine and dimensionally reduce the data. The process of combining is known as clustering, i.e., it classifies data intents into meaningful groups so that components inside a given cluster are similar to each other but dissimilar to those from other batches. Clustering is beneficial for marketing segmentation for businesses. The dimension reduction patterns decrease the number of variables in a set of data by clubbing similar or related properties for better understanding.

(iii) *Reinforcement Machine Learning:* It refers to a machine application that communicates with a progressive atmosphere or dynamic environment to perform a specific objective (like to order food, to book a cab, or to play a game). As it is applied on different problem areas in order to train and test

the data which may or may not be similar to the required output to achieve maximum efficiency through machine learning. Distinct methods have been acquired which may not fit into these categories, and from time to time, there are instances where one uses a combination of more than one category to reach the required aim.

This machine learning technology when gets integrated with IoT can make a huge impact on the economical aspect of society. The real benefit can be experienced when there is an addition of 5G networks in the same field. Now, next we will be looking at the aspects which make this collaboration of machine learning, Internet of Things, and 5G networking possible and how they proved to have the potential to create all forms of tasks easy, feasible, affordable, and efficient.

Machine learning is a support to many businesses as it allows understanding from the data, automate trading methods, boost productivity, and gradually benefit too [3]. And while corporations and firms are ardent on utilizing machine learning algorithms, they sometimes find it to be challenging. All the organizations are diverse and their courses are unique. But importantly, they often face problems in machine learning which involve basic concerns like company purpose arrangement, individual mindset, and more. The biggest challenges in the adoption of machine learning include:

(i) Remote data and data safety
(ii) Infrastructure essentials for trial and experimentation
(iii) Inflexible business models
(iv) Lack of talented individuals' time
(v) Utilizing implementation
(vi) Cost

3.2 Machine Learning and 5G IoT

IoT device utilization is growing day by day. This extensive usage of IoT produces enormous volumes of data. This data can be efficiently treated by the use of machine learning to infer several beneficial insights that can enhance services and influence the lives and technologies deeply. In the modern-day world, the growth is being witnessed in the consumption of IoT devices. As the number of devices increases, more data will be generated as the data is proportional to the consumption of these devices. Data concerning social patterns of trade and sustenance makes the machine learning ready for the interpretation that can benefit our work and life in a positive way. Machine learning will support IoT devices to operate in a better manner, creating a pleasanter lifestyle for society.

The domain of machine learning is developing and undeviating, accompanying the growth of the IoT. IoT elements such as sensors and nano cameras are now omnipresent; installed in mobile phones, laptops, PCs, parking stations, and shopping stores; and used for traffic control, medical industry, and even in-home

appliances [4]. There is a huge amount of IoT devices prevailing in the world, and there is no change of its decrement soon. These devices collect large measures of data that is supplied to machines through the Internet, permitting devices to "learn" from the information given and make them more useful. In IoT, it is necessary to record that an individual method/factor can generate gigantic quantities of data at each instant. This information from IoT is dispatched to servers to build better machine learning standards. By the year 2021, the world will witness a huge share of IoT devices which are estimated to be around 20 billion. Data gathered by those devices often concerns the development of automation. Furthermore, machines can absorb more efficiently and can backside their shortcomings [4, 5].

Let us take an example; suppose there are a set of people visiting a doctor and we have scanners, sensors, and nano cameras to get the data about those patients. If the data is fed to the system via the Internet, then the data can be analyzed. Now, if the graphical representation of patients having fever is visible, then it may be considered that the machine or device has not imbibed it fully. Parallel to this, if the system can identify other diseases that a patient possibly has by observing their face and body structures, then it can be considered that the machine is fully developed and has learned the needful and is now intelligent. Collecting, processing, interpreting, and remaining ready to "think out" practicing IoT data need a lot of infinite computational and commercial support to achieve marketing and machine learning benefits. Today, the IoT joins numerous areas such as production industries, healthcare, construction industry, transportations, traffic, purchasing, and so on. Data accumulated from these regions can positively make the foundation of learning meaningful and efficient.

One major trait of 5G is the capacity to foretell action over the network and control them. Machine learning is accommodated to serve in 5G networks as it needs large volumes of data batches to foretell the accuracy of the activity. Machine learning seems to be a necessary component of any networking system as it is more complex than the few initial network generation. It works at higher frequencies, offers more elaborate configurations, and operates more advanced connectivity devices. The MIMO antennas which stand for multiple inputs multiple outputs used by 5G networks can manage multiplied data "communications" simultaneously across the same data signal [6].

This implies that more data transmission can be done without affecting the transfer of other data across the same network. As more machines tend to connect to the 5G networks, it creates a difficulty in managing all the traffic without the cooperation of machine learning. The 5G networks will be ready to examine data patterns and communication, enabling a dynamic transmission of data. A completely working 5G network will not happen without AI and ML as they are capable of making judgments by themselves. It gives supplementary penetrations into the shape of the network by giving other skills and functionalities for the error, administration, and issues related to security as shown in Fig. 14.3.

The factors can be quickly controlled and resolved for the networks and systems are informed about the handling issues before they become difficult. For instance, a weak network plan is found more quickly based on the machine learning analysis

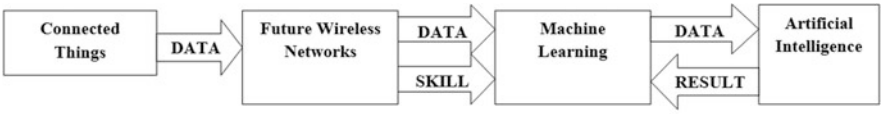

Fig. 14.3 Machine learning and 5G networks

of past traffic models. System failures are speedily rectified as the identification is done even before showing a negative impact across the network and are alleviated efficiently, something tough to do in profoundly complex operations without machine learning.

To check the number of hardware tools required to empower a 5G network by introducing the ideology of virtualization or network slicing. Network slicing refers to the usage of a single shared network with parallel running multiple virtualized networks. For example, firms can run a single network slice to lower the delay in the system that requires higher reliability; on this particular device, the employee traffic is handled by another slice. A 5G network-stimulated car has one network slice for the scenarios like autonomous driving facility and other slices for other functions and a different slice for the car features like radio, navigation system, and AC. Installing network slices is confined on a 5G network as there is a requirement of manual configuration. ML and AI will aid this service and find a way to reduce the complexity of the systems. This will assure that all information exchange is routed based on the need of the device and ensures the configuration settings to be appropriate.

3.3 Applications of Machine Learning

The potential and prevailing applications are [5–7]:

(i) *Agriculture:* Agriculture is undoubtedly one of the most vital human pursuits. More helpful technologies imply higher yield. This holds the human race more satisfied and healthier. According to some surveys, global food generation will rise by 70 percent by the mid-twenty-first century to keep up with global demand. The selection of IoT and ML in the agricultural area is also progressing swiftly where the total number of related device demand seems to grow at a very high rate reaching 75 million in 2020. In smart agriculture, all communications between farmers and agricultural methods are converted to be data-driven. Even analytic tools are presenting the correct information at the appropriate time. Gradually ML will provide the reason to surmount and automate the agricultural sector. It is encouraging to discover patterns and derive information from enormous quantities of data.

(ii) *Healthcare:* Today, smart, supported living circumstances are required for patients with chronic health issues, and to the rescue comes home healthcare.

This connects the patient's medical history and semantic illustration of the individual care process with the powers to watch the living situations with the integration of technologies like machine learning, Internet of Things, and 5G networking. The combined healthcare structure can produce significant additions while enhancing general wellbeing.

IoT devices in this sector are the nano sensors connected to the patient's skin to measure sugar levels, heartbeat, blood pressure, etc. This inexperienced data is forwarded to the database that remains in the highly guarded cloud platform. The doctor can obtain the data of the earlier prescriptions and use advanced ML algorithms to prescribe specific medications to patients at distant places if demanded. Thus, subjects at the house can be protected from sudden health hazards like heart attacks.

(iii) *Maintenance:* In 2017 "Internet of Trains" project was launched. Embedded sensors in tracks and the trains were set up in countries like Russia and Spain. Employing the data input from the sensors, they raised a machine learning design to recognize signs if the track or the rain was about to fall. They later use the overtaken observation to find the area which requires repairs.

(iv) *Surveillance from CCTV:* This is the largest in scale example of IoT with ML. This has enabled facial identification software to be appointed with the CCTV cameras. The technology is nowadays being used in cities, airports, railway stations, and malls to catch hold of criminals. This technology also has its drawbacks as it interferes with personal space or privacy.

(v) *Supply Chain:* As businesses now have a lot of data and want to know about the responses from their customers, they are practicing this technology to adapt their list accordingly. They guide various companies like Uber and Walmart to attain a better position in the service market.

3.4 Various Challenges Encountered While Applying ML

These days companies are overwhelmed with data that arises from IoT projects and are exploring ML and 5G networking to help and maintain these devices. It is difficult to control and secure vital data from these operations [8]. There are features to IoT similar to a data warehouse, connectivity, safety, app advancement, integration of the system, and even methods that are growing in this area. An extra layer of complexity among the IoT takes functionality to the next level.

Significant trials that businesses face amidst IoT and ML are the application, access, and interpretation of IoT data. If one has a set of input from varied origins, then one can run some analytical process. Despite the need for prediction regarding the events, the companies need to learn the process of using this technology. Numerous firms are shifting to the cloud platform providers as these businesses offer a variety of services to store data and serve it for data analytics and machine learning models. They also support in building plans, dashboards, and other designs

to imagine the data these models produce. Overall, IoT, ML, and 5G networking are coupled to implement high clarity and power of the wide array of devices attached to the Internet [9].

Futurists assume that ML and the IoT will convert the market deeply showcasing revolutions. Are there distinctive kinds of uncertainties in this technology? This is the new question to which one can only answer that with any developing technology, one ought to admit both the advantage and risks that occur with the main adoption. The technology that is tested against all the odds can be considered safer and more profitable.

5G networking will facilitate a modern age of possibility for everyone. The capacity to manage and transfer data from anyplace in the world to wherever one want that to in the shortest possible time will change the way one used the technology. It will unbar the minds of technology specialists as they consider new, progressive, and innovative ideas to develop the potential and subsistence of our markets. In this age of connection and connectivity, people have many technologies to sustain their daily necessities. In this situation, IoT, ML, and 5G networking are developing as a possible answer for queries faced by the service sector in several sectors. Adding machine learning and IoT to mix with 5G will make matters even more impressive. Intelligent machines will be able to experience learning with methods intended to assist and optimize our experiences. With the precise succession of machine learning and the Internet of Things, one can enjoy unparalleled levels of accomplishment and computerization with the help of 5G networks. It will stimulate discovery in all phases of growth, improving the way one abide and operate for ages to come.

4 Big Data Analytics

As the world is becoming more and more digitalized, it involves the generation of data from different resources which in result has led to the growth of big data. Big data refers to a large and complex set of data that can be present in any format, and the analysis of such data is called big data analytics [17, 18]. Big data and DM are two unique things; while the two of them identify with utilization of huge data sets to deal with the information that will fill our need, they are two distinct terms in the part of activity they are utilized for. Enormous data alludes to an assortment of huge data sets (e.g., data sets in Excel sheets which are too huge to possibly be dealt with without any problem). Data mining then again alludes to the movement of experiencing an enormous lump of information to search for applicable or relevant data. The difference between the two can easily be understood through Table 14.1.

Big data is symbolized by 3Vs which are velocity, volume, and variation. Volume can be referred to as the quantity of data that is generated every day by various sources around us, while velocity means the amount of development and in what speed the data is accumulated for analysis. Variety is responsible for the flow of information or data which is structured, unstructured, semi-structured, etc. The not

Table 14.1 Difference between big data and data mining

Features	Big data	Data mining
Definition	It is a term used to refer to a large amount of data set	It is a technique used to excerpt useful data from a raw data set
Aim	It mainly aims at gathering, storing, and processing a variety of data	It mainly aims at analyzing data and finding relationships between them
Type of data	It consists of structured, unstructured, and semi-structured data	It consists of relational databases and structured data
Applications	It is used for dashboards and prophetic means	It is used for strategic judgment purposes

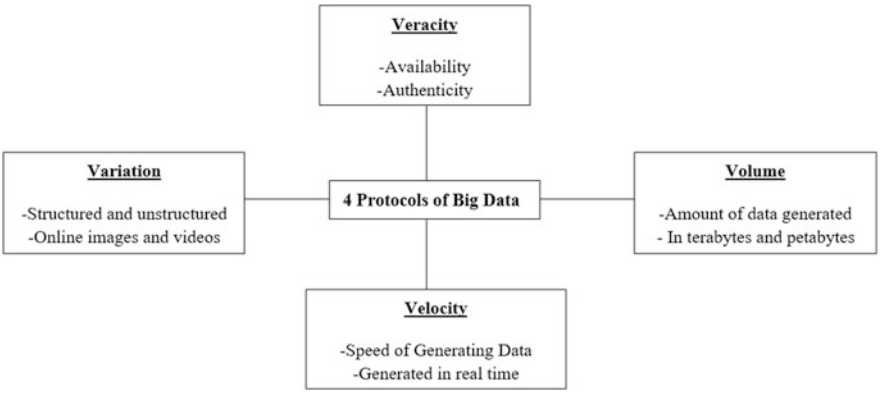

Fig. 14.4 Big data protocols

so popular V, that is, veracity, which comes fourth is actually the possibility and liability. The major aim is to successfully achieve and follow these 4Vs as shown in Fig. 14.4. Big data analytics has become such an important aspect because all the IT and computer industries are producing a huge amount of data that can only be taken in use after its analysis as that all information present in the form of big data is not necessarily required for analysis or decision-making process. Industries are fascinated to invest in customized findings of big data.

4.1 Challenges in Big Data Analytics

Initially, data warehouses were used to process big data, but precision and accuracy were the main concerns that were faced [19, 20]. The major issue in the analysis of big data is the deficiency of coordinated communication between database systems and analytic tools. The first challenge for big data analysis is the unavailability of storage methods which can be due to the increased speed of input/output. In such scenarios, the data approachability should be the main concern for better

representation. In earlier times, hard drives were used to store the data, but it became steady and became less reliable due to the random input/output production. To avoid this problem, the idea of solid-state drive (SSD) was introduced.

The second challenge in the implementation of big data analysis is the multiplicity of data, which refers to the growth of data sets in an undefined pattern. As a result, the already existing algorithms might not respond in an expected way and insufficient time whenever dealing with high-dimensional data. The only solution possible in such situation is to shift the attention to designing storage systems and to use appropriate big data analysis tools which can guarantee the result when the data comes from multiple sources.

The next third most important challenge is data scalability and security. All establishments have their proper policies to protect their sensitive and private information, which is the main concern for big data analysts as there is an immense security risk which is related to big data due to which the reliability of data and information is becoming a major problem. The possible ways in which security can be improved are by implementation of the techniques of authorization, authentication, and encryption.

For processing the high-dimensional data and solving the above issue, various tools have been developed. The major three tools are [21, 22]:

(i) *Apache Hadoop and MapReduce:* The commonly known and successful software platform that can be used in big data analysis is Apache Hadoop and MapReduce. MapReduce is a programming representation for large data sets which are based on the famous divide and conquer algorithm. This method is generally executed in two steps which are Map step and Reduce step. Hadoop has two types of nodes which are master node and worker node.
(ii) *Apache Spark:* Apache Spark is an open-source processing structure of big data which is built for speed processing and sophisticated analytics.
(iii) *Apache Drill:* Apache Drill is a specially built system for interactive of big data analysis. It has much more flexibility and the ability to assist different sorts of query languages, data formats, and data sources.

4.2 Big Data Analytics and IoT

Big data analytics has widely proven itself as a major asset in the field of IoT to increase the potential of the decision-making process. The most important feature of IoT that should be taken care of is the examination of information related to "connected things." Big data analytics with the integration of IoT aims at filtering a large set of data on the fly and storing it using diverse storage methods/technologies. It is well known that most of the data collected are unstructured as it is collected directly from web-enabled "things"; thus, big data usage becomes necessary to perform rapid analytics with large data to permit organizations to obtain fast intuitions; they can build speedy decisions that can interrelate with both humans

and virtual devices. The incorporation of IoT and big data analysis allows sensing and triggering devices that in turn provide the ability to share information across platforms and develop a successful operating image for enabling unconventional applications [14, 23].

It is required to embrace big data in IoT applications as these technologies have been individually acknowledged already in all the fields related to IT and business. These technologies are correlated, and if they are jointly developed, then it would lead to discoveries and a series of achievements. They act as a way of opportunity for each other. For example, the deployment of IoT has displayed an increase in the amount of raw data generated and, thus, offers chance of development. The advantages of this interaction don't end here; the application of big data technologies in IoT also facilitates speed to the research and business-related models of IoT. The relation between IoT and big data can be classified into three categories to ensure proper administration of data.

The first major step includes the management of IoT data resources, so that various connected devices can use big data applications to interconnect with each other. For example, the huge quantity of data sources is generated due to the interlink age of devices such as CCTV cameras, traffic lights, and smart home devices which produces the data in different formats. The second step involves the generation of "big data" that are based on their characteristics (3Vs) velocity, volume, and variety.

These large amounts of data are then stored in big data files that are by default in shared, dispersed, and fault-forbearing databases. The last step involves the application of various analytics tools such as MapReduce, Spark, Splunk, and Skytree that can inspect the storage of big IoT databases. All four levels define how the raw data generated in IoT is successfully managed using big data analytics as shown in Fig. 14.5.

4.3 IoT Architecture for Big Data Analytics

The architecture of IoT can be defined and established on IoT domain abstraction and recognition. The architecture is like a reference model that specifies the relationships among different IoT levels, such as traffic, smart home, transportation, and smart health. On the other hand, the architecture for big data provides an idea of data abstraction. There are various kinds of architectures depending upon its application. For example, there is an IoT architecture of IoT associated with cloud computing at the center, and it represents a model of end-to-end interconnection among shareholders in a special kind of framework also known as cloud-centric IoT framework which leads to proper comparison with the suggested or default IoT architecture [25]. The architecture can be only accomplished by logical pervasive recognition, data analytics, and proper representation of information with IoT which seems like a unifying architecture. Nonetheless, the present architecture focalizes on IoT concerning communications. The proposed or default architecture is considered the one that integrates IoT as well as big data analytics.

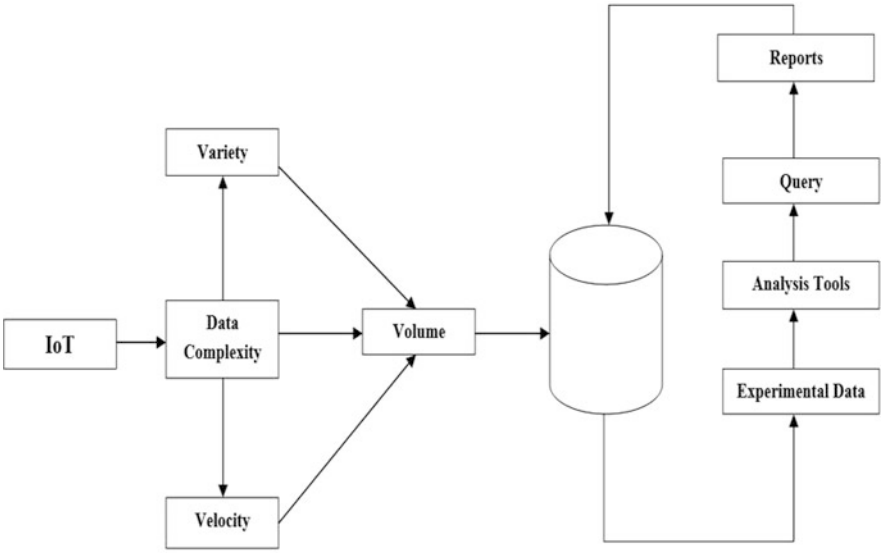

Fig. 14.5 Correlation between big data analytics and IoT

The IoT architecture combined with big data analytics includes the sensor layer that as the name suggests has the sensor devices along with the objects that are connected with each other through a wireless network as shown in Fig. 14.6. This communication and connection is a wireless network that can be RFID, Wi-Fi, ultra-wideband, and Bluetooth. The interaction of the Internet and other web browsers is possible today due to the IoT gateway. Big data analytics come into play in the upper layer in the architecture and a huge amount of data obtained from sensors and are then stored in the cloud which, later on, become accessible through big data analytics-based applications. These applications include API management to aid in communication with the processing engine.

The correlation among IoT and big data provides different utilizations in various fields [25–27]:

(i) *E-Commerce:* Big IoT data display non-uniformity, volume, and real-time data-related processing characteristics. It has numerous applications in almost every industry. The major achievement areas of analytics are in growth of revenue, the increment of customer size, the precision of sale forecast results, product enhancement, risk management, and upgraded customer segmentation.
(ii) *Smart Cities Applications:* A large amount of data is collected from applications used in smart cities which provide new opportunities that can only be gained through suitable analytics to analyze big IoT data. Today, all devices can link to the Internet and create an environment that is smart, and then the detail is passed and processed using big data. Therefore, big data plays a major role in transforming every zone of the economy of a country.

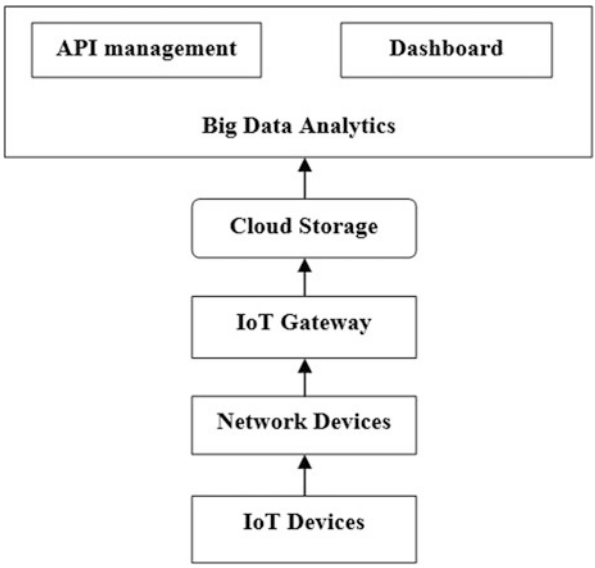

Fig. 14.6 IoT Architecture with big data

(iii) *Market and Logistics:* IoT plays a major part as an emerging technology in the field of retail, market, as well as logistics. In logistics, containers are tracked, platforms and the container is kept using RFID. Moreover, development in IoT technologies can smooth dealers by giving various benefits. IoT devices produce huge amounts of data on a daily basis. Therefore, big data analytics helps to categorize the data and hence allows enterprises to attain insights from the huge sets of raw, undefined data generated through IoT-enabled technologies. Application of data analytics can uplift the shipment experience of users. Besides, retail enterprises can gain large amounts of profit by analyzing user data and by predicting the trends as well as demands of products.

4.4 Big Data Analytics in 5G-Enabled IoT Systems

The interaction of big data techniques with 5G distributed applications shows up an inconvenience, as these methods generally require a huge amount of technical resources. The convergence of 5G cellular, IoT, and data analytics has to lead to great advancement in the information and communications technology (ICT) industry. The combination of such technologies has successfully built a leading path for new business models. Moreover, it also helps in technical innovation and innumerable opportunities for applications of all those industries that are dependent on Telecom and IT services [28, 29]. 5G ensures the creation of intelligent networks, while IoT ensures connectivity of application services to remote sensors, and the

huge amounts of data produced by these IoT connections are analyzed further by big data analysis.

Big data analytics is now no longer considered a future aspect or something which requires a second thought; in fact, it plays a very important part in the growth of 5G standards which further enabled intelligence over the applications and business. Today the world traverses the role of analytics in the conditions of 5G, to understand major technology trends or patterns and business leaders that outline the path to 5G services and applications, and, finally, provides a maturity model of 5G analytics and networks. It has to lead to the transformation from being context-aware to becoming cognitive along with intuitive [35].

Data analytics is at the highest spot seeking full advantage from 5G network characteristics. For example, high-bandwidth, low-latency, mobile edge computing (MEC). The big data at rest and the data in motion can come into reality due to the ability of 5G to aid gigantic connectivity over multiple devices which is further supported by the distributed computer architectures. It also produces the potential to convert big data into real-time insights and allows interaction with intelligence. Big data analytics plays a dual role in 5G. While, on the one hand, analytics resume to help diverse business applications of 5G webs, on the other hand, it also plays an important role in the roll-out of 5G network operations. Data analytics is compatible with 5G technology systems.

Big data analytics along with machine learning are used to develop an energetic mechanism by anticipating the approval distribution of the data in 5G networks. It is believed that this method can enable the structured usage of network resources and return a better experience for users. The first task is accumulating the raw data, i.e., the user traffic, and then the big data program plays a role in predicting the customer requests by pulling out the useful data, like Location Area Code, Hypertext Transfer Protocol, Tunnel Endpoint Identifier TEID and (TEID)-DATA to control the data levels. The content popularity can be achieved by the information collected from the collected raw data. This task has been experimentally tested on 16 base stations, as part of an operation of network, and it successfully resulted in complete request results and 98% backhaul offloading [30].

Various applications in which the goals of association among these technologies have been seen are:

(i) *Mobile Cloud Computing:* Today a smart and intelligent world is a gift to us due to mobile cloud sensing and 5G network. Major important applications such as the safety of the customers and the healthcare domain require analytics in actual time. Due to promises made by a new 5G interface such as prioritization-based MEC-supported local analytics, and the reaction time improvements, 5G is now able to lay an establishment for supporting mission-analytical edge analytics as well as tangible Internet applications. 5G allows not only sensing and analyzing at the edge but also activating actuators to activate responses within minimum required time due to which all data proceed from cloud to an excess of endpoints and vice versa.

(ii) *Comprehension/Cognitive Analytics:* Alternatively, conventional illustrative analytics with regular BI reporting and analytics in 5G transform itself into machine/deep learning. Analytics in 5G in the future will evolve to such an extent that it will be able to not only learn from the context but also predict what is going to happen next and advise the following finest step that needs to be taken. It will also help to learn from the past behavioral mistakes for picking the most suitable decision. For completely autonomous applications, it will automate the next step. Data analytics has already-built-in insights that can accelerate decision-making, and due to the convergence of 5G, a huge amount of information will be accumulated and processed, which will be fastest in the history, thus leading to cognitive intelligence applications.

In the case of a sober network with limited capacity, data analytics is like a boon with utmost importance: the network can collect so much data, but before the exposure of big data analytics, there were not that many resources to process it. 5G networks are not anything but limited as well as simple, making it possible for analytics to provide on the 5G assurance while also taking full advantage of 5G resources. Gartner had predicted that by upcoming years, some percentage of 5G networks will be commercially launched by networks-based mobile communications service providers (CSPs). According to the Hype Cycle report, it is mentioned that in upcoming years,

5 Convergence of Machine Learning, Data Mining, and Big Data Analytics for 5G-Enabled IoT

When 4G was proving to be a new era of expansion then the convergence of Machine Learning, Data Mining, and Big Data Analytics for 5G enabled IoT sets as a new bar of extension. With this comprehensive integration of technologies, 5G has increased efficiency, reduced decision time, and also created strong real-time analytics. The whole idea of 5G-enabled Internet of Things has emerged an adequate amount of satellites to send signals from highly populated places to the poorest places of the world. These satellites need data to be processed, and the outputs are generated on the same; in this scenario, big data analytics play a vital role. They harmonize the ground data concerning the satellite, and every microscopic detail is transferred to the satellite as inputs, and then ultimately high speed and efficient data are provided to the users [31, 32].

Researchers, industrialists, and organizations are investing in these upcoming technologies by providing them more aggregate of machines and unstructured data so that further refurbishing of the results takes place. Technology is increasing rapidly, things are getting more complex and user-friendly, and to meet the new demands of the customers, it is very supreme to adapt to the new significant function of these technologies. Communication is the foremost way to connect people; 5G has proved to be viaduct for millions of people. Machine learning, data mining, and

big data analytics have been pillars of the stability of 5G networks, and by virtue of contribution of Internet of Things platforms, the whole mechanism has become efficient, and the output time is reduced. Ultimately, this revolutionary convergence is a stepping stone for the upcoming generation of networks.

6 5G-Enabled IoT Case Studies

5G will be most often utilized by organizations to achieve IoT communications. It is believed that 5G will be an essential program that will enable artificial intelligence widely [33, 34]. Some of the case studies through which one can able to understand about how all the technologies are correlated to each other are explained as follows:

(i) *Case Study: Smart City*

Till now it has been discussed how machine learning makes systems adapt to data and create outputs from the same, how data mining provides the amorphous data to the systems to be used as inputs, and how data analytics deals with the manipulation and organization of the data. According to the smart city architecture, the three major constituents which are the pillars of the smart cities are:

(a) Technological Stack – It deals with the backend situation of the cities which includes servers, machines, algorithms, etc. The convergence of machine learning, big data analytics, and data mining focuses on the satisfaction of people's needs by providing them with swift networks that can make their communication fluent.

(b) Human Resources – It is more of like the frontend of the whole system. The IoT services are now ready to cater to the needs of everyone. There are open resources for learning, observing, and creating new projects from these networks. They simulate a crucial role improving the economy of the country.

(c) Organization Factors – Once both backend and frontend are ready, it's time to link them, and hence, the organization factors work as the middleware for both ends. For close analytics, they test the networks at different frequencies to get superior results. The advancement of smart cities has been assisting in time-saving, energy-saving, and money-saving as well. The IoT has proved to be a stable manifesto for the smart cities concept. It has held the back of databases, pieces of equipment, algorithms, etc. Earlier it was an enormous challenge to summarize the whole strategy of providing a stable network system to the people into a single primitive network.

(ii) *Case Study: Mobile Networks*

Mobile Networks is one of the major necessities of today which provides the advantage to millions of users to operate any application, services, etc. Technologies like machine learning, big data analytics, data mining, and the

Internet of Things are responsible for connecting them with the high-tech servers. These servers will supervise the traffic and also analyze them.

Network providers like JIO, Airtel, Vodafone, etc. are one of the biggest companies in terms of users and services. These companies operate on the substantial data principles which redeem and then examine the data generated through the mobile Internet provided to the users. The data which is produced is in millions, and to handle it and store it in a particular order is impractical for a single person; therefore, devices with massive storage space are employed. As compared to normal storage devices, these high-tech devices have ten times more capacity to store any sorts of data.

7 Conclusion

The 5G-enabled IoT paradigm has become an indispensable aspect of our everyday lives. However, IoT gadgets are obliged in communication and computation which are the bottlenecks in the advancement of versatile, smart solutions utilizing AI methods. Also, in making new innovations and stage upgrades for the future includes quick IoT advancement, application development, and solid examination of high volume IoT information through data mining and big data analytics.

Throughout the chapter, it has been discussed how, with the help of machine learning, the system can react and produce output based on data provided and also analyzed the role of data mining which provides unstructured data as the input and how big data analytics simulates a crucial role for monitoring and analyzing data provided by data mining techniques. 5G networks are a new era of technology whose integration with machine learning, data mining, and big data analytics can be transformed into further reactive networks.

The chapter also focused on IoT platforms, convergence of machine learning with IoT platforms, convergence of data mining with IoT platforms, and convergence of big data analytics with IoT platform. The concept includes how machine learning enhanced efficiency of 5G networks, how data mining furnish data for 5G networks, and how big data analytics reduced the time consumption of the 5G networks. With the detailed theories about the 5G networks, it was time to explore some real-time case studies for a better understanding of the concept. In the chapter, two case studies are presented which will bestow a closer look at the mechanism of 5G networks with the help of these revolutionary technologies. The first case study is about smart cities in which the role of 5G networks is highlighted, and the second case study is about mobile networks where the concept of MSNs (mobile social networks) is elaborated.

Lastly, how the convergence of machine learning, data mining, and big data analytics with 5G networks can be done is explained and how they are shaping the world to be more user-friendly. The chapter is a complete package of information that will allow users to explore new things. Technology is improving every second and the sapiens have to adapt the change for their survival in the world.

References

1. M. Mohammed, M.B. Khan, E.B.M. Bashier, *Machine Learning: Algorithms and Applications* (CRC Press, Boca Raton, 2016)
2. M. Kubat, *An Introduction to Machine Learning* (Springer, Cham, 2017)
3. M. Ghadge, D. Pandey, D. Kalbande, Machine learning approach for predicting bumps on road, in *IEEE International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT)*, (IEEE, Piscataway, 2015), pp. 481–485
4. L. Atzori, A. Lera, G. Morabito, The internet of things: A survey. Comput. Netw. **54**, 2787–2805 (2010)
5. T. Koreshoff, T. Robertson, T. Leong, Internet of Things: A review of literature and products, in *the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration*, (ACM, Adelaide, 2013), pp. 335–344
6. M.A. Alsheikh, S. Lin, D. Niyato, H.P. Tan, Machine learning in wireless sensor networks: algorithms, strategies, and applications. IEEE Commun. Surv. Tutorials **16**(4), 1996–2018 (2014)
7. A. Smola, S. Vishwanathan, *Introduction to Machine Learning*, vol 32 (Cambridge University, Cambridge, 2008)
8. Maruti Techlabs, https://marutitech.com/challenges-machine-learning/
9. M.S. Mahdavinejad, M. Rezvan, M. Barekatain, P. Adibia, P. Barnaghid, A.P. Shethb, Machine learning for internet of things data analysis: A survey. Digital Commun. Networks **4**(3), 161–175 (2018)
10. J. Han, M. Kamber, J. Pei, *Data Mining: Concepts and Techniques*, 3rd edn. (Morgan Kaufmann, Boston, 2012)
11. A.L. Buczak, E. Guven, A survey of data mining and machine learning methods for cyber security intrusion detection. IEEE Commun. Surv. Tutorials **18**(2), 1153–1176 (2016)
12. G.V. Krishna, Data mining processes, applications and challenges for IoT. Int. J. Trend Res. Dev. **4**(3), 157–160 (2017)
13. K.K. Lammatha, Data mining on 5G technology IoT. Int. J. Eng. Comput. Sci. **8**(5), 24655–24660 (2019)
14. A. Kaloxylos, Application of data mining in the 5G network architecture, in *The Thirteenth International Conference on Digital Telecommunications*, (IEEE, Piscataway, 2018), pp. 39–44
15. A. Savaliya, A. Bhatia, J. Bhatia, Application of data mining technique in IoT: A short review. Int. J. Sci. Res. Sci. Eng. Technol. **4**(2), 218–223 (2018)
16. A.M. Njeru, M.S. Omar, S. Yi, S. Paracha, M. Wannous, Using IoT technology to improve online education through data mining, in *International Conference on Applied System Innovation (ICASI)*, (IEEE, Piscataway, 2017), pp. 515–518
17. M. Hilbert, Big data for development: A review of promises and challenges. Dev. Policy Rev. **34**(1), 135–174 (2016)
18. H. Hu, Y. Wen, T.S. Chua, X. Li, Toward scalable systems for big data analytics: A technology tutorial. IEEE Access **2**, 652–687 (2014)
19. S. Madden, From databases to big data. IEEE Internet Comput. **16**, 4–6 (2012)
20. R. Casado, M. Younas, Emerging trends and technologies in big data processing. Concurrent. Comput. Pract. Exp. **27**(8), 2078–2091 (2015)
21. Apache. Hadoop MapReduce, https://hadoop.apache.org/
22. Apache. Apache HBase, https://hbase.apache.org/
23. Y. He, F.R. Yu, N. Zhao, H. Yin, H. Yao, R.C. Qiu, Big data analytics in mobile cellular networks. IEEE Access **4**, 1985–1996 (2016)
24. I.A.T. Hashem, V. Chang, N.B. Anuar, K. Adewole, I. Yaqoob, A. Gani, E. Ahmed, H. Chiroma, The role of big data in smart city. Int. J. Infrastruct. Manage. **36**, 748–758 (2016)
25. D. Puthal, R. Ranjan, S. Nepal, J. Chen, IoT and big data: An architecture with data flow and security issues, in *International Conference on ICT Infrastructures and Services for Smart*

Cities International Conference on Cloud Networking for Internet of Things Systems, IISSC & CN4IOT, (2017)
26. S. Talari, M. Shafie-Khah, P. Siano, V. Loia, A. Tommasetti, J. Catalão, A review of smart cities based on the internet of things concept. Energies **10**, 421 (2017)
27. J. Yang, Y. Han, Y. Wang, B. Jiang, Z. Lv, H. Song, Optimization of real-time traffic network assignment based on IoT data using DBN and clustering model in smart city. Future Gen. Comput. Syst. **108**, 976–986 (2017)
28. R. Chaiken, B. Jenkins, P.K. Larson, B. Ramsey, D. Shakib, S. Weaver, J. Zhou, SCOPE: Easy and efficient parallel processing of massive data sets. Proc. VLDB Endow. **1**, 1265–1276 (2008)
29. A. Imran, A. Zoha, Abu-Dayya. A.: Challenges in 5G: How to empower SON with big data for enabling 5G. IEEE Netw. **28**(6), 27–33 (2014)
30. F. Chang, J. Dean, S. Ghemawat, W.C. Hsieh, D.A. Wallach, M. Burrows, T. Chandra, A. Fikes, R.E. Gruber, Bigtable: A distributed storage system for structured data. ACM Trans. Comput. Syst. **26**(2), 1–26 (2008)
31. B. Ryder, F. Wortmann, Autonomously detecting and classifying traffic accident hotspots, in *ACM International Joint Conference on Pervasive and Ubiquitous Computing and 2017 ACM International Symposium on Wearable Computers, Maui, HI, USA*, (2017), pp. 365–370
32. M.A. Al Mamun, J.A. Puspo, A.K. Das, An intelligent smartphone based approach using IoT for ensuring safe driving, in *IEEE International Conference on Electrical Engineering and Computer Science (ICECOS)*, (IEEE, Piscataway, 2017), pp. 217–223
33. Research and Markets, https://www.researchandmarkets.com/reports/4968358/5g-artificial-intelligence-data-analytics-and
34. Business Wire, https://www.businesswire.com/news/home/20200207005390/en/2020-2025-Worldwide-5G-Artificial-Intelligence-Data-Analytics
35. S. Tanwar, S. Tyagi, N. Kumar, *Multimedia Big Data Computing for IoT Applications: Concepts, Paradigms and Solutions, Intelligent Systems Reference Library* (Springer Nature, Singapore, 2019), pp. 1–425