Chapter 5
The Influence of 5G, IoT, and Blockchain Technologies in Industrial Automation

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1 Introduction

Since the dawn of mankind, human beings used to manufacture goods by hands or with the help of working animals. These methods were sufficient only for a short period. As time passed by and the global population grew rapidly, the demand for goods also increased subsequently. Existing manufacturing methods posed to be time-consuming, tedious, and inefficient to facilitate the production of goods on a large scale. Therefore, these challenges led to the advancement of an efficient technique called automation.

Automation in simple terms can be defined as a technique that employs machines and the latest technologies to make a process operate without the requirement of manpower. Earlier human input was used to ensure the functioning of these machines. However, with the employment of automation, the requirement of human intervention is negligible. In its initial stage, automation was a simple assembly line of workers that consistently performed repetitive tasks daily. The problem with this approach was that the majority of these tasks posed to be monotonous, dangerous, and unsanitary. Modern automation has become much more advanced. In terms of industrialization, it refers to the use of control devices like information technologies, robots, computers, etc., that handles and manages various processes and machines of the industry. However, to take full advantage of these benefits, the utilization of the Internet of Things (IoT) was crucial.

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IoT is an interconnected network of industrial devices, objects, processes, and humans through which participating entities can operate, communicate, and utilize the collected data. This is done to further boost the manufacturing operations and productivity. With the rapid increase in the number of IoT devices every day, larger network bandwidth is required. This can be fulfilled by the latest 5G technology. Along with network bandwidth, 5G technology also provides other benefits like low latency, ubiquitous connectivity, and efficient utilization of energy. However, there still exists a lack of security between the communication of the industrial objects of the network [22]. Therefore, blockchain technology is employed to provide security to the network.

Blockchain is a public ledger that is decentralized and immutable by nature. This ensures the transparency and authenticity of the received data, that is, the data is not altered or modified without the consent of anyone present in the network. Any change in the transaction of the network is first verified by all the nodes present in the network and then only it is recorded. Along with this, these nodes present in the network are also granted permission to acquire and transmit the respective transaction. Thus, the primary features of the blockchain (such as security, privacy, and trust) induce a positive influence on further development and innovation of industrialization.

Modern industries are benefited from IoT, Blockchain, and 5G communications. Figure 5.1 shows concisely how each technology is shaping modern industries. Automation in industries is known for a long time. However, with the advent of industrial IoT (IIoT), automation has advanced considerably and contributed to bigger industrial philosophy commonly known as industry 4.0. Figure 5.2 further illustrates this relationship. This figure is plotted using Google Ngram viewer [15] that shows how these terms (industry 4.0, smart manufacturing, IIoT, 5G, Blockchain, industrial automation) evolved during the years 2005–2019. Figure 5.2a

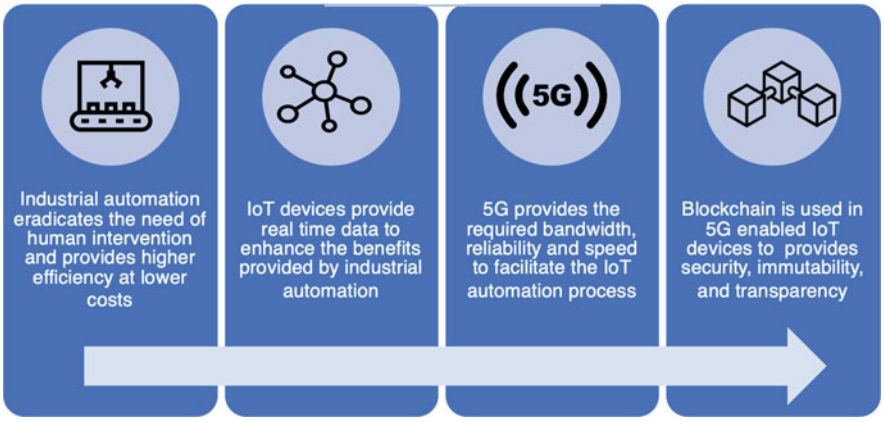

Fig. 5.1 Evolution to Modern Industrial Automation

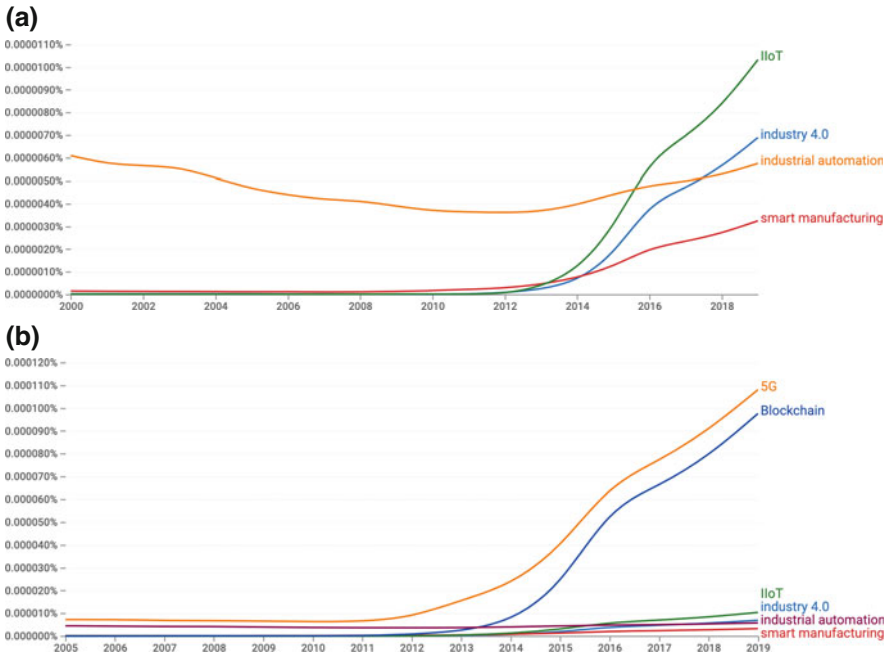

Fig. 5.2 Trends of various contributing technologies for Industry 4.0

shows that industrial automation is commonly used even before the term "industry 4.0" was coined. The trend of "industry 4.0" looks similar to IIoT because it is one of the main enabling technology. Figure 5.2b has additional terms 5G and blockchain, which are more frequently used as they are employed in various sectors in addition to industrial automation.

1.1 Motivation

With the advancement towards industry 4.0, a subsequent rise and need for industrial automation have emerged. The latest technologies, such as IoT and blockchain provide promising solutions to facilitate industrial process automation. Furthermore, the integration of the 5G network features has led to the further enhancement of these processes. The novelty of this chapter is that till now, various papers have been published that talk about these technologies, but none of them has addressed the influence achieved by the integration of these technologies. Therefore, this chapter provides an in-depth introduction to enabling technologies for industrial automation. It discusses the fundamentals of each trend separately and elaborates its impact on industrial automation. It also explains how 5G technology is helping in eliminating

bottlenecks in closed-loop automation. It also gives an insight into the applications and influence of these technologies in industrial automation. Lastly, it provides a use case of the integration of these technologies in the banking and finance sector.

1.2 Contributions

In this chapter, we have provided a brief review of the emerging technologies in the various industrial sectors. Mentioned below are the following major contributions of this chapter:

1. Provides a brief introduction of blockchain, IoT, and 5G networks.
2. Discusses the impact of IoT, 5G and blockchain technologies in industrial automation, along with each of their applications towards different industrial sectors.
3. Finally, provides a use case of these integrated technologies in the banking and finance sector.

1.3 Organization

The structure of this chapter is as follows: Sect. 2 talks about the rise of industrial automation, Sect. 3 talks about IoT, Sect. 4 talks about the emergence of 5G wireless networks, Sect. 5 talks about blockchain technology, Sect. 6 demonstrates the use case of blockchain and 5G-enabled IoT in the banking and finance sector. Finally, Sect. 7 concludes the paper.

2 The Rise of Industrial Automation

Currently, there are four stages of industrial automation as illustrated in Fig. 5.3. The first industrial revolution is known as industry 1.0 started during the late eighteenth century. Steam and water-powered machines were developed to replace human labor so that efficient production could be achieved. This soon got replaced by industry 2.0, in which machines that operated on electrical energy were developed to massively further improve the work rate and reduce the expenses. This is because unlike the machines powered by water and steam, electrical machines have proven to work more efficiently. During this period, the first assembly lines were also designed to promote mass production. Later with industry 3.0, the use of electronics and computers first started to automate the process of manufacturing. This helped immensely to enhance speed, accuracy, and productivity. This was soon replaced by the current era we live in—industry 4.0. Industrial automation is the cornerstone

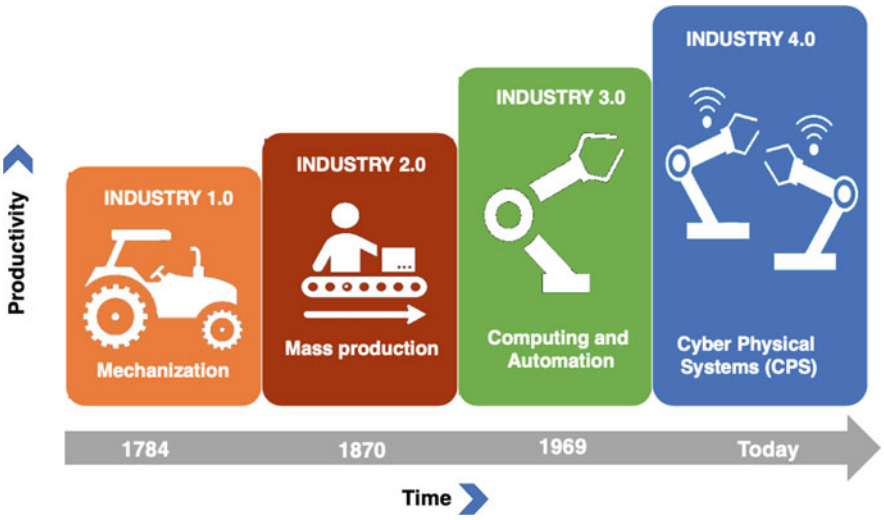

Fig. 5.3 Timeline of the industrial revolution

of industry 4.0, which majorly compromises of various Cyber-Physical Systems (CPS) such as manufacturing facilities, storage, systems, smart grids, and smart machines. This involvement of CPS helped in essentially creating a fully automated environment to ensure that no human intervention is necessary to execute the required tasks.

2.1 Benefits

The beginning of industrial automation brought forward rapid advancements towards various industries as illustrated in Fig. 5.4. Through it, the following major benefits were achieved:

2.1.1 Productivity

In industries, tasks performed by manual labor exhibit certain drawbacks. For instance, humans often get distracted and tired while executing the same repetitive tasks. Moreover, humans often require vacations and cannot operate 24 h a day and 7 days a week. However, with the involvement of industrial automation, continuous mass production can be achieved with ease. The tasks that earlier required multiple workers to complete can now be performed by a single machine. Thus, the productivity levels of the industry can be massively improved.

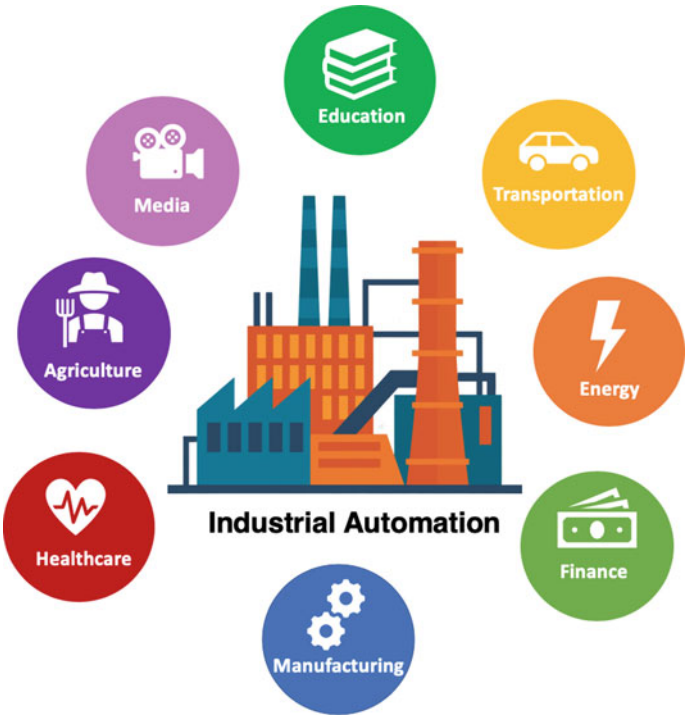

Fig. 5.4 Common industry sectors influenced by industrial automation

2.1.2 Accuracy

Human beings are prone to error and often make mistakes when they are fatigued. Any mistakes made could cause damage to raw materials, components, and final manufactured products. Industrial automation is employed to alleviate human errors and thus improve the quality of products produced.

2.1.3 Safety

As compared to machines, humans are fragile. They cannot be exposed to a dangerous work environment that deals with hazardous materials, extreme temperatures, polluted air, broken equipment, etc. Therefore, industrial automation is implemented to remove humans from hazardous conditions and replaced robots instead.

2.1.4 Costs

Implementing machine and robots pose to be cheaper than recruiting human workers to perform tasks. After the initial capital expenses, the only other cost is in the

maintenance of the machines. This is way cheaper than combining the annual salaries of human laborers. Therefore, these lower production costs and higher productivity lead to an increase in financial gain.

To completely take advantage of these benefits, modern automation integrates the latest emerging technologies like IoT, 5G, and Blockchain. The next sections talk in brief about the impact of these technologies for industrial automation.

3 Internet of Things (IoT)

Today we live in an age where we see the Internet of Things (IoT) present everywhere around us. It has made our lives easier and more convenient to live in. Just like how the discovery of the internet changed the way we communicate to one another, IoT has further taken this connectivity to a whole new level. Through it, multiple devices are connected to the internet to facilitate man to machine and machine to machine communications. These devices could be anything from a simple light bulb to huge industrial machines. However, just like any technology, there is a certain process that needs to be executed to complete the desired tasks. Mentioned below are the following steps that a typical IoT system executes (Fig. 5.5):

1. Sensors are used to gather data from the environment. The nature of this data depends on the device it is attached to. It could be anything from a temperature sensor to heat sensors. Moreover, a device could even have multiple sensors attached that can collect a variety of different data.
2. The received data needs to be sent to a processing server (e.g. a private cloud); however, it requires a medium to be sent. Therefore, the sensors are connected to the cloud via a communication technology such as Bluetooth, Wi-Fi, Ethernet, etc. The type of communication technology employed depends upon the IoT application, cost, range, and power consumption.
3. Once the data is delivered to the cloud, a software application is used to perform the necessary actions on the acquired data. This action can be anything like checking the energy consumption of the devices to air quality. If the situation requires the need for user interaction, then an alert is sent to users via their phones, smartwatches, laptop, etc.

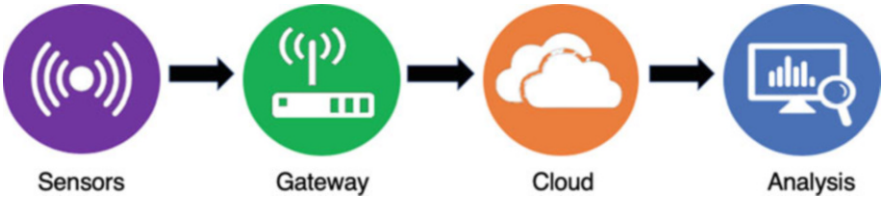

Fig. 5.5 Process flow of IoT components

4. Historical data can also be used to obtain valuable insights that can help in the smooth operation of the devices. For instance, predicting the possible future malfunction of machinery.

3.1 Impact on Industrial Automation

The implementation of IoT in industrial automation has completely revolutionized the way industries operate. It helped to create an environment of intelligent machines that could operate tasks more effectively than human beings. Mentioned below are the major benefits that are provided with the implementation of IoT in industrial automation:

3.1.1 Improvement in Energy Efficiency

Consumption of a large amounts of electricity leads to higher costs. IoT is used to significantly reduce massive energy consumption. From the data collected through IoT, companies can identify the devices that consume a lot of energy. Furthermore, the data collected can help to create operation profiles that instruct the machines when to operate and when not to conserve energy. Systems that drain energy or consume more energy than required could mean that the system itself might be faulty. IoT connectivity helps to address such systems. IoT connectivity can also further help to create energy profiles of an individual or several facilities. This information would help to provide an overview of how to smoothly execute operations while keeping in mind the impact on the energy consumption of such operations.

3.1.2 Predictive Maintenance

Predictive maintenance is a technique that helps to identify the condition of equipment in order to estimate when maintenance is required. This technique is essential to ensure the smooth operations of the machines present in the industries. However, it requires analysis of a large amounts of data and executing complicated algorithms. Therefore, an IoT based solution is employed to eradicate these challenges. With IoT, large terabytes of data can be stored and various machine algorithms can be executed in parallel on different computers to forecast any potential damages and identify when industrial equipment could most likely fail to operate.

3.1.3 Reduction in Operational Cost

Advancements brought towards IoT benefit the industries to reduce operational cost and maximize profits. Therefore, industries that maximize the utilization of IoT will

thereby obtain maximum profits. This is because, with the help of IoT devices, real-time information can be obtained instantly. This information can help to facilitate a variety of operations. For instance, in the manufacturing industry, the IoT devices can constantly monitor the equipment for any faults, that is predictive maintenance can be achieved as explained earlier. The implementation of such techniques can also reduce power consumption, this in turn helps to further reduce the overall costs of the industries.

3.2 Industrial Applications

The execution of the IoT process helps to ensure the smooth operations of the industrial processes to provide a closely connected and intelligent environment. This would bring benefits across diverse industries. Mentioned below are some of the major industrial applications:

3.2.1 Agriculture

Maintaining the quality of the soil is crucial to ensure that high-quality goods can be obtained from it. The utilization of IoT helps to ensure this. With the help of the IoT sensors, farmers can get the detailed information regarding the current state of the soil like temperature, moisture content, nutrient deficiency, acidity level, presence of diseases in plants, etc. This information lets farmers implement necessary actions that can help to enhance the present condition of the soil. Moreover, the farmers can deduce the optimal time to plant seeds and identify the presence of diseases in plants/crops.

3.2.2 Healthcare

Before the emergence of IoT, the interaction between patients and healthcare professionals was carried out via face to face visits, phone calls, or text messages. These methods did not provide healthcare professionals with the ability to constantly monitor the status of their patients. However, with the advent of IoT enabled wearable healthcare devices, continuous monitoring of patients is possible. With remote monitoring, the interactions between doctor and patient have become much easier and efficient. Furthermore, it also helps to immensely reduce hospital stay and re-admission of the patients. Another application of IoT is the use of smart beds equipped with sensors that help to constantly monitor vital signs of patients like blood pressure, temperature, pulse rate, etc.

3.2.3 Energy

The energy sector has undergone a variety of changes over the past 20 years. It has been estimated that the total energy consumption across the world would increase to 40% in the near future [11]. This means that there is a need to develop smart energy solutions that would help to achieve efficient use of energy resources. The use of IoT can help to achieve this goal. For instance, the installation of smart energy meters can be used to facilitate the management of the electrical network. Furthermore, the establishment of communication between consumer and service providers can help in the acquirement of a large amounts of data to detect a fault, repair it, and enable decision making. Consumers can benefit from IoT as the data collected can help them to gain insights about their consumption history and the optimal way to reduce their energy consumption if possible.

4 The Emergence of the Fifth-Generation (5G) Wireless Network

The first generation (1G) of the wireless network had first emerged during the 1980s. Within just 40 years, the wireless communication network has completely transformed itself. It now plays a key role in the development of modern infrastructure. The evolution of wireless network took place almost every 10 years. With every evolution, along with better speed and connectivity, various services were also provided. Figure 5.6 illustrates a summary of the evolution from 1G to 5G networks.

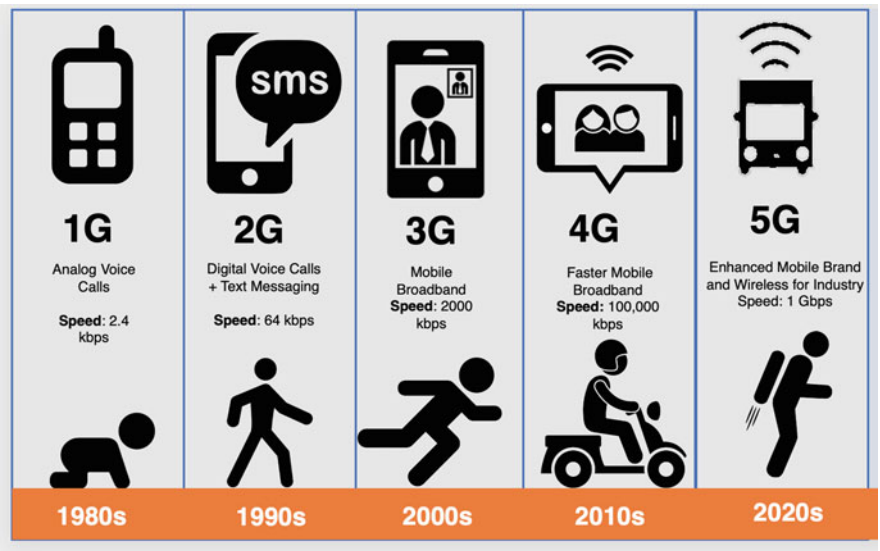

Fig. 5.6 Evolution of mobile communications from 1G to 5G

4.1 Impact on Industrial Automation

Industrial automation powered by IoT, because of the various benefits it provides, proved to be successful in enhancing the automation process; the total number of IoT devices employed in different industries rose rapidly. As illustrated in Fig. 5.7, it has been estimated that the total number of IoT devices is set to increase to 75.44 million by 2025 [10]. This massive rise in IoT devices means that a rise in the amount of data will also be transmitted and processed.

Existing technologies are inadequate to handle massive volumes of data with expected reliability or latency requirements. Therefore, 5G implementation can help to facilitate the handling of a large number of IoT devices. Apart from this, the introduction of 5G network helps to facilitate IoT processes in the following ways:

4.1.1 Improved Reliability

5G networks provide a more reliable and stable network, which is extremely important for the various applications of connected IoT devices. This feature is important in applications such as the implementation of security locks, cameras, and other kinds of systems that provide monitoring services and require real-time data as input.

4.1.2 Faster Data Rate

The success of IoT majorly depends upon the speed with which communication can take place. With the introduction of the 5G network, data transfer speed rose rapidly.

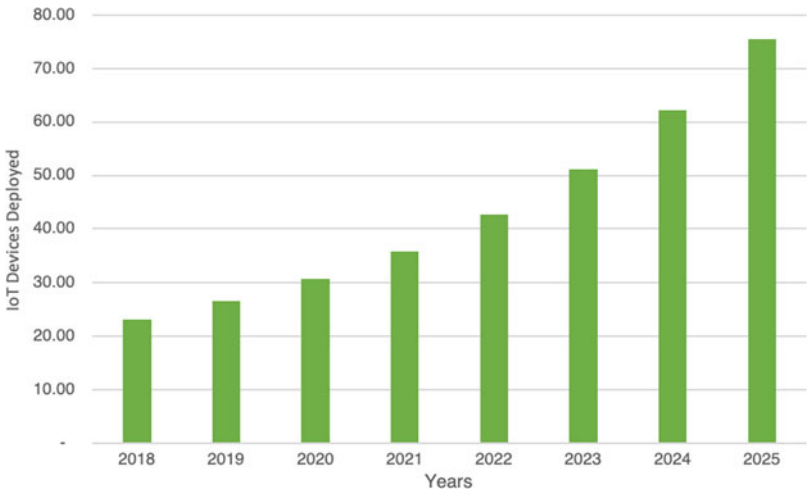

Fig. 5.7 Growth in number of IoT devices

Table 5.1 Comparison of mobile networks in terms of their influence on the industrial applications [23]

Generation	Industrial impact
1G	No impact
2G	Provides remote control and facilitates text messages to and from remote machines
3G	Provides video monitoring, remote access to machines as well as remote condition monitoring
4G	Facilitates live remote access
5G	Facilitates autonomous logistics, machines, edge computing

The increase in data rates allows IoT devices to communicate and share data faster than ever. This feature would benefit various IoT based applications such as the operations in smart healthcare, smart manufacturing, autonomous vehicles, etc.

4.1.3 Lower Latency

5G provides lower latency that is about ten times faster than the traditional 4G network. This low latency will immensely help to facilitate actions that can occur in industrial plants, remote transport, remote surgery, autonomous driving, etc. (Table 5.1).

4.2 Industrial Applications

Now we are quickly shifting and preparing ourselves to the next generation of mobile networks: the fifth generation of mobile networks, also known as 5G. The introduction of the 5G network has completely transformed the way we perform our everyday tasks. It is expected to be the next big thing in terms of mobile connectivity. And has extensively helped in the operations of major industries as illustrated in Table 5.2. Apart from just being a successor of previous networks, the 5G network aims to foster the era of digitization. This is mainly because of the following key features it provides over 4G networks [17]:

1. Ultra-Reliable Low Latency (URLL): In this feature, the communication can happen with a latency of less than one millisecond, which is about 50 times faster than 4G.
2. Enhanced Mobile Broadband (eMBB): This feature allows the data transfer rate up to 10 Gbps which is about 100 times more than what 4G can provide.
3. Massive Machine-Type Communication (mMTC): This feature provides scalable connectivity for a large number of devices, which is 100 times greater than what 4G can provide.

Table 5.2 5G application scenarios across industries [1]

Industry	5G service	Few example cases
Manufacturing	5G smart factory application	Flexible 5G slice, smart toolboxes, production monitoring, remote maintenance/inspection, VR transparent factory
Energy	5G smart power application	Remote control of power distribution systems, advanced tele-metering, robot inspection, electric vehicles (EVs)
Healthcare	5G mobile remote medical care application	Ward inspection with the remote robot, mobile medical vehicles, remote surgery/tests, connecting massive numbers of devices in one hospital ward
Transportation	5G smart transportation application	In-vehicle entertainment, V2V, V2I, and V2P are for automatic driving, vehicle formation, collision avoidance
Security	5G video integrated application	HD video IPTV, remote surveillance, VR/AR live broadcast
Municipal administration	5G public services and society government application	City monitoring for safety, security, environment, cleanliness, smart citizenship services
Education	5G smart park application	Holographic projection, virtual innovation teaching, intelligent recognition

Thus with the implementation of 5G network we will be able to attain a future where not only are mobiles, computers, and laptops connected to the internet, but also other objects like industrial equipment, grocery products, and city assets. This will help to foster the business growth for the organization and completely change the way we communicate, operate in business, and live as a society.

5 Blockchain Technology: The Next Best Thing

For centuries, humans have experimented with different ways to obtain goods and services. At first, the barter system was implemented and used for years. In this system, people exchange goods and services in return for other goods and services. However, this system soon got replaced with the use of coins and money. To further enhance the speed and efficiency of transactions, credit card and electronic payment methods were introduced. Internet and mobile phones have also played a major role in facilitating the process of electronic payment. Nevertheless, these methods still experienced certain challenges such as dependence on a third-party validation, extra payment for transaction costs and service fees, vulnerability to fraudulent activities, etc. Therefore, challenges have led to advancement towards a new form of digital currency cryptocurrency.

Employment of cryptocurrency brought forward several features like faster transactions, anonymity, and the absence of third-party intermediaries. Currently,

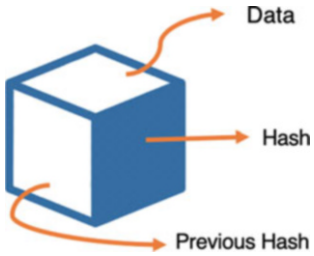

Fig. 5.8 A typical block in blockchain

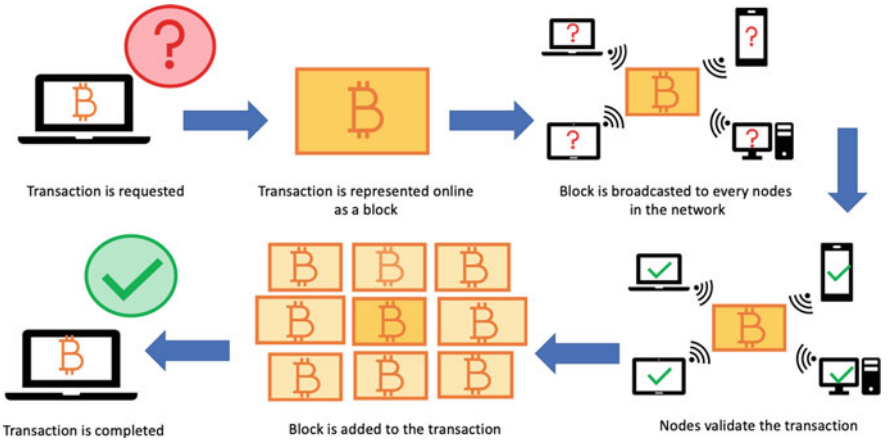

Fig. 5.9 Process depicting inclusion of a new block in blockchain

several cryptocurrencies are present in the market. Bitcoin, Ethereum, Ripple, Litecoin, etc. are some of the known cryptocurrencies. Among them, Bitcoin is the most widely used cryptocurrency that was founded by Satoshi Nakamoto in 2008 [18]. To facilitate the features of cryptocurrencies, an underlying technology called blockchain is used [21].

Blockchain in layman terms is simply known as a chain of multiple blocks. It is a distributed, decentralized public ledger that is open to anyone. Figure 5.8 illustrates a typical block that compromises of three basic elements: data, a cryptographic identifier called a hash, and the hash of the previous block. The data stored in the block can be anything and it depends upon the application. For instance, the bitcoin blockchain stores information about the buyer, seller, and the amount. The function of the hash is to uniquely identify the block and its contents. It is just like our fingerprint, unique in nature and specific to each block. However, the hash is created by a hash function that maps the block data of arbitrary size into a single fixed value size. The third element of the block is the hash of the previous block, which helps create the chain of blocks. It is due to this type of connection that blockchain can provide a secure environment. Figure 5.9 depicts the steps that are required to be executed in order to successfully add a block in the blockchain network.

(a) Valid Blockchain

(b) Invalid Blockchain

Fig. 5.10 Typical Blockchain network

After the block is created, it is impossible to change the contents of the block without the hash itself getting changed. This is because once a block is created, its hash is always calculated. Any change in the block will change the hash too. That is, a hash is useful to detect whether any changes occur in the block. Changing a single block will make the corresponding blocks invalid. A visual representation of a valid and invalid blockchain network is illustrated in Fig. 5.10.

However, the sole use of hash is not enough to prevent any changes in the block. This is because computers are much more advanced today and can easily compute thousands of hashes per second. This means that the data in the block can be easily tampered as all of the hashes of other blocks can be recalculated to make the blockchain valid. Therefore, blockchain compromises of the proof of work algorithm to overcome this challenge. The proof of work is a mechanism that helps to slow down the process of the block creation process. Another way in which blockchain gains security is by being distributed. That is, rather than employing a central entity to manage the network, blockchain utilizes a peer to peer network. This means that anyone who enters the network gets a complete copy of the blockchain. In addition to this, every node in the network has the right to verify a new block and ensure that it is intact. The verified block is then added to the

blockchain network. To successfully tamper with the blockchain network one must satisfy the following conditions:

1. Firstly, every block in the network must be altered.
2. Next, the proof of work for each of these blocks must be re-constructed.
3. Finally, complete control of more than 50% of the network must be achieved.

Only after the execution of all the above conditions, the blockchain network can be altered. With the current technology, it is computationally infeasible to match these conditions.

5.1 Features

Apart from providing security to the system, blockchain also provides other major features. Mentioned below are some of them [3, 24]:

5.1.1 Decentralized

The main role of the blockchain network is to store and copy data (cryptocurrencies, contracts, and other digital assets) across all the nodes present in the network. This means that the network is decentralized in nature, that is, it does not depend upon a central entity, but a group of nodes that maintain the network. Therefore, through the implementation of the decentralized blockchain network, owners will be able to gain direct control over their account by using their private key. Furthermore, this also helps to provide common people the power and rights to perform actions on their assets as they wish for. Stock exchange, transactions are done in real estate, personal identification, etc. are some of the major areas where the decentralization feature can benefit.

5.1.2 Distributed Ledger

A distributed ledger is a database that is sent to all the nodes present in the blockchain network. Whenever a new block is added, a message is broadcasted to make sure that every node has the updated version of the ledger. This feature facilitates the applications beyond digital currencies, as it removes the requirement of dealing with a central authority to record information. As this feature allows the ledger to be stored on several devices that are located in different locations, it, therefore, helps to protect the system in case of data loss caused by devices or servers during downtime.

5.1.3 Immutable

Blockchain is an immutable distributed ledger that is decentralized in nature. It is because of this nature that the information once stored in it cannot be altered easily. This helps to create trust in the transaction record. In case a data is added to the block it first needs to be approved by all the parties present in the network. Without consent from the majority of the nodes, the blocks cannot be added. Furthermore, the user cannot go back and change, edit, delete, or update the appended block. Therefore, this helps to create an environment that is transparent and free of corruption.

5.1.4 Consensus

All participants present in the network must come in terms with a given set of rules that determines the validity of the block. A consensus algorithm is used to put forward a common agreement for all the nodes present in the network. In case, a block violates any of the given rules, then that block is considered as invalid and thus does not get added to the network. Therefore, this feature helps to provide a sense of trust between the nodes present in the network as every node can be assured that every other node follows the ratified rules. At present, there are various types of consensus algorithms that are based upon different principles. Some of the commonly known algorithms are: Proof of Work (PoW), Proof of Stake (PoS), Proof of Burn, Proof of Space, Proof of Activity, etc. Paper [19] talks in brief about each of these algorithms and other common algorithms.

5.2 Impact on 5G-Enabled IoT

The major challenges IoT presently face is security, privacy, compatibility, and centralization [8]. Fortunately, the majority of these challenges are solved via blockchain with 5G enabled IoT. The major feature of blockchain is that its architecture is decentralized in nature. Therefore, its integration with IoT helped to eradicate centralization and make transactions more secure and transparent. Apart from this, the employment of blockchain with IoT provides the following additional benefits:

1. Blockchain uses a distributed ledger, which is unalterable in nature. This helps to remove the need for trust among the involved parties. That is, no single party has control over the massive amount of data produced by the IoT devices.
2. Blockchain helps to store the data collected by the IoT devices. This helps to further enhance the present security levels. This is mainly due to the encryption mechanism that blockchain provides to protect its data. Thereby, making it difficult for hackers to gain access to the network.

3. Blockchain also provides the smooth processing of the transactions of billions of IoT devices. With the increase in the number of devices, the distributed ledger facilitates the processing of the massive transactions obtained from these devices.

5.3 Impact on Industrial Automation

The implementation of blockchain technology in industrial automation processes will bring numerous benefits [13]. Some of the major benefits are mentioned below [9]:

5.3.1 Improved Transparency

With the implementation of blockchain technology, the transaction history can become more transparent. Through it, all the nodes are now able to share the same information that can be updated via consensus. To change a single transaction record, all the transactions present in the network would need to change, which is not possible. This allows anyone in the network to view all the information present in the network. Furthermore, it also helps to ensure that the data on the network is transparent, accurate, and consistent. Therefore, this feature can benefit various industries like real estate, automotive, manufacturing, etc.

5.3.2 Better Security

Blockchain helps to ensure that the information stored is not vulnerable to cyber-attacks. This is because of the way the transactions are stored in the network. That is, first the transaction must be validated by the nodes present in the network, only after it is approved that it is encrypted and linked to the previous transaction. Furthermore, the information stored is the same across all the nodes present in the network. This is the reason why it can be difficult for hackers to alter or change the stored data. This feature would therefore immensely help in industries such as healthcare, government, finance, etc., to protect sensitive data. Thus, blockchain can help to prevent any unauthorized activity that can occur on the stored data.

5.3.3 Enhance Traceability

This feature helps to solve the issue of tracing back the products to their origin. That is, it helps industries whose products have to go through a complex supply chain. This is because blockchain helps to store information related to the present status of the transaction such as how the goods are manufactured, shipment location, how they are managed, etc. As this data is immutable and can be easily shared

with the supply chain network, it, therefore helps to provide extensive tracing and tracking abilities. Whenever the transfer of goods is recorded on the blockchain, the entire journey of the blockchain can be seen. This helps to provide validation to the authenticity of the assets in industries like drugs, agriculture, etc.

5.4 Industrial Applications

There are many research efforts/proposal/implementations studying the use of blockchains across various industries [2, 16]. For example, blockchain applications are studied for drones [6], finance [20], and autonomous vehicles [7]. This section highlights some of the key applications:

5.4.1 Agriculture

The agriculture sector is another domain that can greatly benefit from the major features that blockchain provides. For instance, it can help to provide an immutable record from origin to the retail store of any product [14]. This would help to create a sense of trust and transparency for the consumers regarding the products they buy. It can also help in enhancing the productivity and efficiency of smart farming. For example, the data gathered by the IoT devices can now be stored in a blockchain and be executed for particular actions. This would, therefore, help to enhance the quality of the crop and the quality of farming.

5.4.2 Energy

Blockchain technology can help improve the energy sector. Through it, the following three major benefits can be achieved: reduced costs, the sustainability of the environment, and enhanced transparency for stakeholders. For instance, it facilitates peer to peer transactions, that is the users can directly trade energy [25]. This feature is useful for energy resources that are renewable like wind and solar energy. This would thus allow prosumers to enter the market and act as suppliers too. Moreover, by employing a decentralized architecture, the consumers can now purchase energy suppliers directly from the utility providers. This would help to reduce costs.

5.4.3 Healthcare

With the rising human population and medical conditions, the need for optimal healthcare facilities is also rising. Fortunately, 5G enabled blockchain has promised to provide a variety of applications in the healthcare domain [2]. For instance, it helps to provide data security to clinical trials done during research and experimen-

tation. Since the data stored in a blockchain is immutable, it also does not allow any tampering of this sensitive data stored. It can also protect the privacy of the patient. That is, sharing of the patient data to a third party like pharmacies can be done with protecting the identity of the patient.

6 Blockchain and 5G-Enabled IoT Use Cases in Finance Sector

As mentioned in the earlier sections, the emergence of blockchain, 5G, and IoT helped to disrupt the way industries operate. The banking and finance sector is one such industry that has observed a wide range of implementation of blockchain technology [5]. The majority of the top banks have started to incorporate blockchain technology to leverage the financial services that they offer. Bank al Etihad is an example of a bank that has already started using blockchain technology to enhance their paperwork and documentation processes [4]. Furthermore, they have also incorporated blockchain to help their customers verify and securely issue confidential documents. Deutsche Bank, HSBC, ING are examples of other banks that have also implemented blockchain technology to enhance their operations and services.

6.1 Characteristics

This is mainly because of the inherent characteristics of blockchain that helps to facilitate the execution of operations and services in this sector. Mentioned below are the following ways on how the characteristics of blockchain technology help the banking and finance sector:

6.1.1 Decentralized Trust

The primary feature of blockchain is that it helps to track and verify transactions. This enables the organizations and the customers to process their respective transactions without the need of a third party or a centralized bank [12]. Various banks have implemented blockchain technology mainly because it consists of a shared infrastructure in which the control is distributed among all the nodes present in a given transaction chain. This helps to immensely reduce any possible counterparty risks.

6.1.2 Enhanced Security

The reason why blockchain is so secure is that once any data is added to its network, it is impossible to tamper with the data. Furthermore, as it is shared by all of the nodes present in the network, it is difficult to hack the network. The decentralized architecture of the blockchain helps to ensure that there is no central point of failure in the network. This allows it to effectively resist any attacks.

6.1.3 Efficient Transactions

The elimination of a centralized entity/third party helped to immensely improve the settlement time and the transaction time of a transaction. Because of this, the transactions can be processed at any time and any day of the week. Furthermore, the transactions can also be done in a faster manner as compared to the traditional methods. This will allow more transactions to be completed at a given time.

6.2 Challenges

Just like any other technology, blockchain also faces few challenges. Therefore, we have mentioned below some of the major challenges that needs to be addressed before implementing it in the banking and finance sector.

6.2.1 Scalability

Although blockchain technology is a prime focus in the financial industry. It however is not capable of handling the large scale of financial transactions that occur daily. This is because multiple nodes are required to validate every transaction. This could lead to a reduction in the transaction speed and an increase in the cost per transaction. Therefore, it is critical to consider before deploying blockchain on a large scale.

6.2.2 Cost

Another challenge faced while deploying blockchain technology is the high cost faced during its initial setup. This makes small companies and banks hesitant to invest in something that does not guarantee a promising success. Therefore, it is important to address this issue before a company thinks about deploying blockchain to facilitate its operations.

6.2.3 Policies and Regulations

One of the major issues faced by banks is the fact that blockchain suffers from the lack of clarity of policies and regulations. Currently, there is no set of standard rules and regulations regarding the transfers done with cryptocurrencies. Unless and until a formal regulatory framework has been established, banks cannot deploy blockchain to facilitate its services.

7 Conclusion

Automation of industrial processes, to meet the conservative business goals, is ever increasing with the help of modern technologies such as IIoT and 5G. IIoT facilitated cooperation among the multiple connected entities for intelligent decisions and subsequent actions. The latest 5G technology has provided the required support for real-time, reliable, and low-latency communications. With so many crucial advanced process control and data analysis applications depending on the IIoT network, there is an increased need for proper access control. Blockchain offers a decentralized tamper-proof robust mechanism for transaction management, which is well-suited for IIoT applications. Blockchain technology in 5G-powered IIoT showed a wide variety of applications and industries started adopting them. This trend is going to continue and benefit various industrial sectors. In parallel, there will be lots of research to improve the scalability, cost efficiency, and standardization of blockchain technology.

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