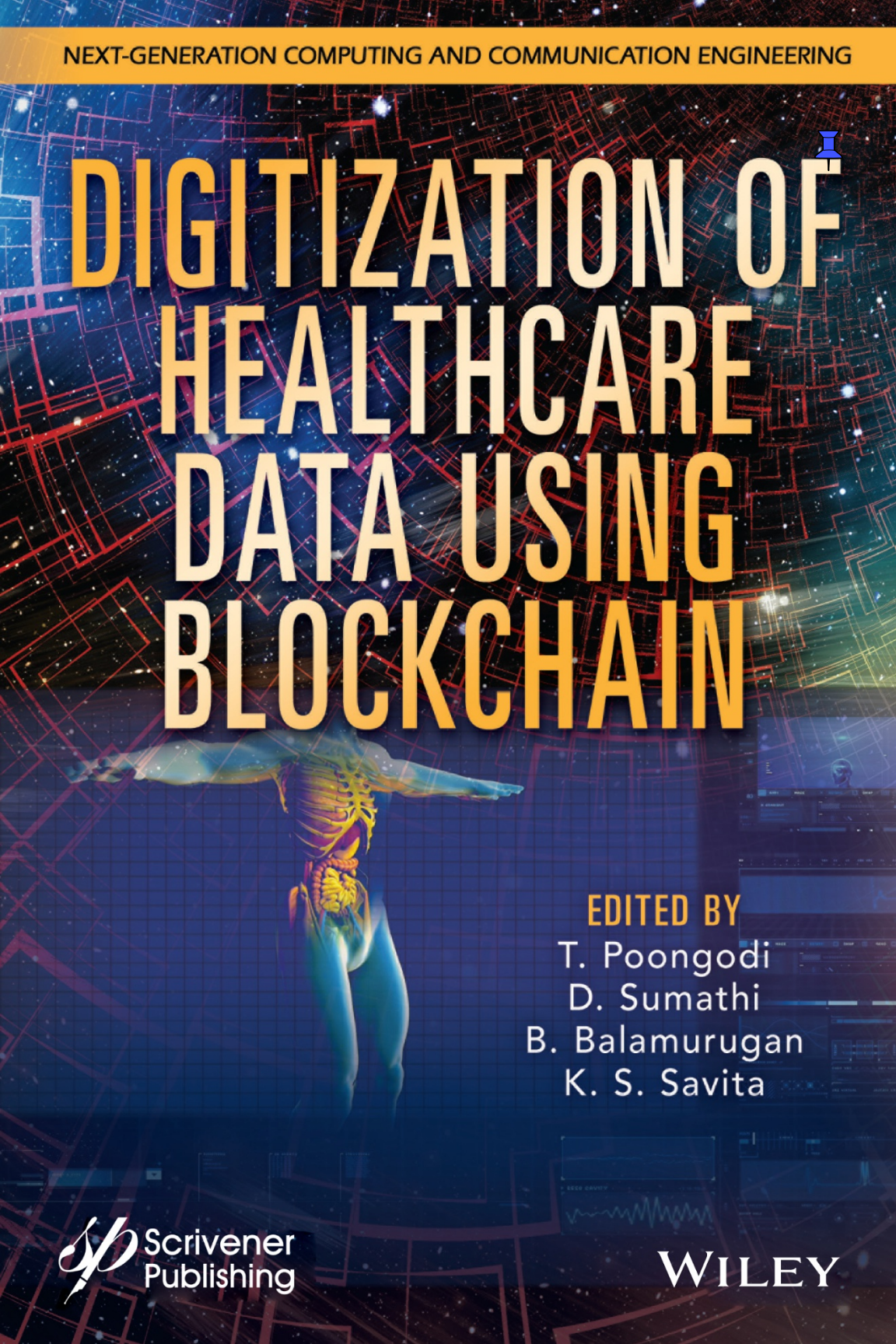
NEXT-GENERATION COMPUTING AND COMMUNICATION ENGINEERING

DIGITIZATION OF HEALTHCARE DATA USING BLOCKCHAIN



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Digitization of Healthcare Data Using Blockchain

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Preface

The revolutionary changes taking place in healthcare domains have attracted the attention of various researchers. Accessing effective, affordable and innovative healthcare is considered to be one of the necessities of modern life. Hence, the need has arisen to empower the digitization of health data in order to make healthcare systems more efficient. By implementing an electronic health record (EHR), progress has been seen in terms of the quality of healthcare. Based on this observation, blockchain technology has gained momentum by gathering all stakeholders in the healthcare sector to solve prevailing challenges. Thus, all of the above factors have driven the editors to propose this book with the goal of enhancing the knowledge of researchers in this state-of-the-art technology and facilitate learning by exposing students, professionals and research scholars in various domains to the information provided by several contributors who are specialists in their areas. This specialized information associated with the incorporation of IoT and blockchain might motivate readers to develop various frameworks along with applications for solving the challenges in various sectors associated with the healthcare domains. Toward this end, a brief description of the information contained in the 12 chapters of this book is presented below.

- Chapter 1 provides a comprehensive review of current research topics, challenges and future prospects in blockchain technology. It also presents various use cases of blockchain technology.
- Chapter 2 explores the intervention of geospatial blockchain analysis in the healthcare industry and also presents policies associated with information security and privacy protection.
- Chapter 3 presents a thorough study of current state-of-the-art technologies by applying blockchain in healthcare domains.

- Chapter 4 deals with the implementation of smart contract and distributed ledger in healthcare informatics.
- Chapter 5 highlights the deployment of consensus algorithms in healthcare domains.
- Chapter 6 investigates the integration of Industry 4.0 with blockchain from the viewpoint of several applications.
- Chapter 7 discusses the utilization of blockchain technology for solving issues in electronic health records.
- Chapter 8 emphasizes the incorporation of IoT and blockchain for the next-generation healthcare services.
- Chapter 9 proposes algorithms for disease prediction with the help of machine learning algorithms.
- Chapter 10 analyzes the impact of blockchain and machine learning in healthcare services.
- Chapter 11 furnishes the advancement techniques in deep learning and blockchain technology in the health informatics field.
- Chapter 12 equips researchers with applications, such as data management, storage and security, in the field of the Internet of Medical Things (IoMT). Apart from that, a review is presented on future prospects in other domains like claims, bill management and drug delivery.

We thank all contributors for their excellent contributions.

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Evolution of Blockchain Technologies and its Fundamental Characteristics

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Abstract

Blockchain technology facilitates a way to organize business activities, commercial transactions, minimizes costs and time incurred because of intermediaries, and increases trust of the complete ecosystem. Blockchain is a decentralized transaction technology that was first developed for the cryptocurrency known as bitcoin. Since the concept was first proposed in 2008, there has been a growing interest in blockchain technology. The primary traits of blockchain are as follows: provide security, data integrity and anonymity without the involvement of any third-party organization for tracking the transactions, which drives interest in this technology and opens up new research areas, particularly in solving several technical challenges. A systematic review is conducted to present all relevant fundamental concepts on blockchain technology in this study. Our goal is to gain a technical understanding of current research issues, challenges, and future directions in blockchain technology. The focus of this research work is in providing a high-level overview of blockchain from the context of its categories and various use cases. Researchers interested in this area would gain a better understanding of this technology with this article.

***Keywords*:** Blockchain, bitcoin, cryptographic, private, public, consortium

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1.1 An Overview of Blockchain Technology

Blockchain in the early stage is known by cryptocurrency, which is known as bitcoin. It is peer-to-peer network and everyone can use without their authentication details. The public can be a part of blockchain and also carryout transactions. According to Gartner report, the estimation of blockchain till 2030 is $3.1 trillion investment. Blockchain plays a very vital and important role in digital cryptocurrency bitcoin [1]. Blockchain can be defined as a scatter database include information or a set of sheets that spot each and every event and agreement, implement and split into examine parties. The transaction data between sender and receiver can never be removed, and each and every transaction had checkable documentation. Blockchain emulates an assigned database by including information by assimilate information identical across the web in real time. At present has become a slang in both industry and academic community [3]. As one of the most victorious cryptocurrencies, bitcoin has appreciated with its capital retail reaching 1 tn dollars in February 2021. In the beginning, scalability is a colossal have to do cover. The size of bitcoin block is restricted to 1MB, at the moment spam a block is mined regarding about every 10 minutes.

There are some properties of blockchain:

i. It has authenticated data, if data change or improve, it has to be confirmed by users using a cryptographic approach.
ii. It has a database that is secured by cryptographic symmetric and asymmetric public/private key.
iii. The transaction of bitcoin between two devices/parties is very trustworthiness.

Blockchain is conceivable consider as a general ledger, and all carry-out transactions are stocked in a record of blocks. These bonds expend as latest blocks are attached to it continuously. Asymmetric cryptography and allocated consensus algorithms have been executed for customer safety along with register stability. The blockchain technology normally has pointer attribute of decentralized, persistency, anonymity, and audibility. Using these properties, blockchain save cost, improve ability, and increase security.

1.1.1 Evolution of Blockchain Technology

Blockchain has progressed into an additional established technology, and the merchandise for the technology is stretching very fast. The blockchain

contributes fetters market awaiting to enlarge at a CAGR of 81.7% atop predict interval 2021 to 2026. Blockchain technology is most intelligible independent, and consortiums from incompatible pasture are applied on different applications of blockchain that expand far away from the origin of cryptocurrency and other different intelligent models. In the uncondensed shareholder, banking plays the earliest major industry investor in the blockchain. Simultaneously, blockchain flatters as undetectable in the online pursuit, and it is very significant to resolve the cybersecurity problem or prevent from methods of attack.

1.1.2 Significant Characteristics of Blockchain Technology

A blockchain is registered effectively in all production in which benefits are supervised and undertaking takes place. It is very powerful in the main aspect of security, it is imparts immovable fetters of tutelage for both, first is digital and second is physical benefits through its protection characteristics that provide between transaction between two different compatible devices. In Figure 1.1 it is very clear to understand the characteristics of blockchain. There are important characteristics described below as coincidental, security, consensus, and other as decentralized. These details of blockchain are very helpful in the research of following transaction. Transaction is the interchange of recommendation that helps to control under the whole amenities rules. These rules help to up and run, with the help of scripting language as bitcoin and also used for state-of-the-art performance. The behavior of blockchain is very credulous, and it is also delineated to get rid of the requirement for all or one setup to gate transactions. Blockchain can be confidential like public, private, or hybrid modification, turn on their appeal public. In the public blockchain, there are no possessors, and anyone can easily access without any authorization, and they are overflowing broadcast. An example of public blockchain is bitcoin. In private blockchain, there are uses of concession to authorize to read and write to the blockchain. Consensus algorithm and mining are not required as sole operation has possession and power block formation. In hybrid blockchain, it works as public but only for a privileged category, and it is controlled by consensus, privileged dependent using a group of rules concurred by all functions. The different characteristics of blockchain is shown in Figure 1.1.

- **Faster settlement:** The head ascendancy of blockchain technology is that it can pace up settlement, twain by acquiring purge of a shattered gestation framework and

Figure 1.1 Different characteristics of blockchain.

by instrumenting a more settlement rotation. It decides to clasp time transaction between parties (sender/receiver). It helps to settle the payment broadcast to Peer-2-Peer (P2P) network consisting of devices that are known by nodes. The payment between these parties, cryptocurrency involved, consists of all records of transactions or also other information.

- **Distributed ledgers:** It is represents the database that is a two-way split and harmonized covering different sites and foundations. This technology is the one important key of technologies, and it is responsible for conducting the cryptographic. Block represents the records, each block keeps the encipher hash of the last block and checksum onward the transaction data.
- **Consensus:** As it is known, the blockchain works on block, and using blocks create a blockchain, the consensus use for surety that every block is added in blockchain [9]. It is the only version that decides which block is added or rejected.

- **Enhanced Security:** Blockchain automation has superior security, it is almost impossible to shut down the system. In history, bitcoin is the second decentralized and had never been hacked, and the single reason is that blockchain trellis is highly secured by a number of computers, which is known by nodes, and nodes are used to affirm the transaction of bitcoin on this network.
- **Decentralized:** This technology plays a vital role in the administration of resources, for both hardware and also for software [7]. Blockchain is worn in a decentralized procedure where a single person nor groups has control, preferably everyone in concert keep jurisdiction.
- **Immutability:** Generating immutably is the foremost values of the blockchain. Blockchain like bitcoin keeps its register in a never-finished state of redirecting momentum. The database is not hacked because of a third party, a third party keeps the data more secure. To command the bitcoin, first, it needs to command over 51% of the whole market.

1.2 Blockchain Architecture and Its Components

A structure of blockchain is an order of blocks, blocks work as a store in an out-and-out list of transaction information like conventional public ledger [5]. Figure 1.2 refers the architecture of blockchain (a) that represents the connection between parties, whole system, and BitCoin connected with each other and create a blockchain. Multiple devices and academics are

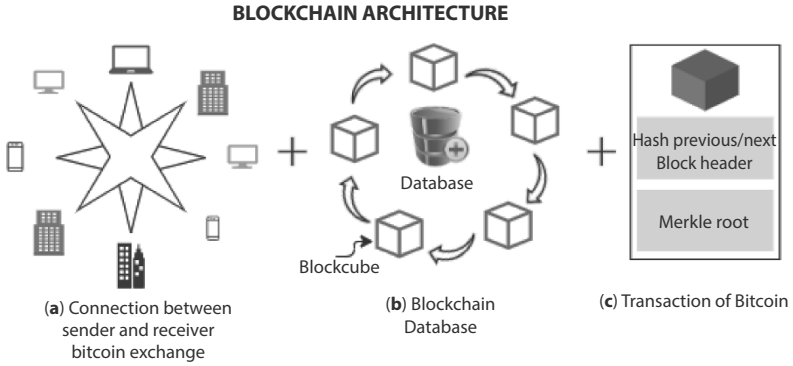

Figure 1.2 Blockchain architecture in different ways. Panel (a) represents the connection between parties. Panel (b) represents the blockchain database. Panel (c) represents the transaction using hash.

connected with each and create a network to exchange their bitcoin. The transaction of bitcoin is highly secure, no one can hack the transaction of bitcoin and it is easy to transfer bitcoin from one place to another place [6]. In a standard consolidate bargain arrangement, a one and all arrangement requires to be certified through the halfway believe in organization, inescapably takes place to the fetch and the staging constriction at the median hostess.

- **Cryptographic Hash Functions:** Cryptographic, this word is mostly used for encryption, and decryptions have been worn for centennial to safeguard military and political confidential. The dialectics was if elucidation of an encipher narrative decision in a consequential communication it should have been formulated by dignitary who realize the confidential leading. In the course of all this terms, the field of paleography was domain of favored few i.e., it was deliberate and accomplished by hardly any [4]. The tendency alteration was Diffie and Hellman, which are ascribe for arrival of public key cryptography in mid 1970s.
- **Asymmetric-Key Cryptography:** It is also known as public key encryption, a structure of information encipher where the encryption key and another correlate with decryption key are dissimilar. A note inscribed with the general (public) key can be deciphered narrowly in agreement with a particular (private) key [2]. The general key and the particular key are connected numerically, even so, it is estimating absurdly to obtain the particular key from the general key. Figure 1.3 shows a key exchange between plain text to decryption document. There are two keys, one is a general key and another is a particular key, a general key is used for
- **Transactions:** A transaction indicates an interchange between parties (receiver to sender and vice-versa). With

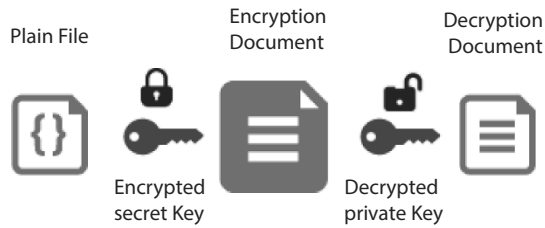

Figure 1.3 Security key exchange.

the help of cryptocurrency, for instance, an arrangement represents a relocation of the cryptocurrency betwixt blockchain user networks. For business-to-business framework, a transaction could be a way of recording a venture happening on the digital or physical forte. It is the most elementary backbone of blockchain system. In the advancement of transmitting the transaction, the customer dispatches the funds, indicating its use in their private key and a particular terminus address. In Figure 1.4, the process of bitcoin transaction is depicted.

- **Ledgers:** It is use for store documentation structure. It helps to keep going the engage recognition incognito, their separate micropayment equilibrium, and an information of fully the veritable compact achieved betwixt crisscross joiner [8]. It somehow differed from blockchain; in blockchain, it creates a sequence of blocks, but in ledger, there are not any chain. A ledger is one kind of database that lays out between collective sites.
- **Blocks:** In simple terms, block helps to store new records of bitcoin transactions that have not yet go in for precedent blocks. Blockchain webwork enjoyer consent applicant deals with the blockchain web via operating system (electronic publishing applications, cellphone applications, electronic handbag, netting services, etc.). The operating dispatch these

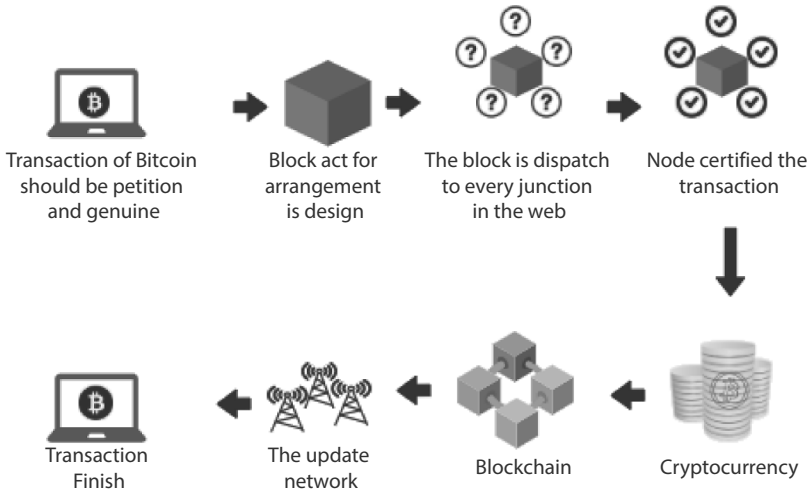

Figure 1.4 Transaction of bitcoin between parties.

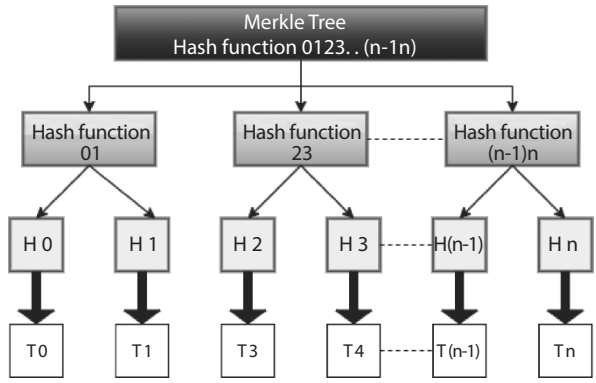

Figure 1.5 Hash tree.

transactions to a junction or a junction inside the blockchain webwork. The selected junction may be nonproducing complete junction, as well as producing junction. The conformed transactions are then breed to the further junction in the web, but they are not taken place itself.

- **Consensus algorithms:** Blockchain automation materialize to overcome the threat and inefficiencies in the vocation agreement. It has transfigured the structure of production and vocation [9]. Blockchain can be expound as a distributed ledger, a portion among the nodes of a vocation network.
- **Merkle tree (inclusion):** Merkle tree is the structure, these data are hashed and integrate until there is an extraordinary radicle hash that act for the whole structure. It is used for verifying data on Merkle tree using mathematical. These are used of cryptocurrency for sure data blocks, which is passed in the middle of peer-to-peer network. Figure 1.5 represents the Merkle tree structure, hash function indicates the set of inputs in a tree structure with their size.

1.3 Comparative Analysis of Blockchain Categories

As blockchain is in its embryonic and the massive rate of acceptance in all level of business activities extending from small-, medium- to large-scale industries in all domains has brought into it a various number of subspecies in its deployment based on the type of network and the access control, i.e., who is allowed into the P2P network and what type of access control

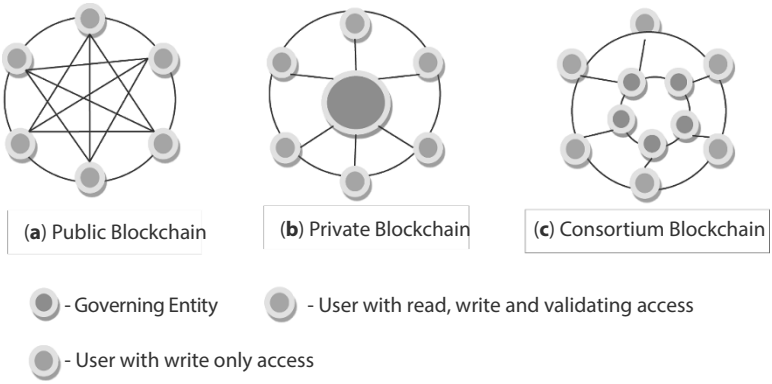

Figure 1.6 Types of blockchain.

they have. The type of blockchain to use is based on the business need and unique to the problem to be solved. Most often, the selection of the paradigm has been deluding to a larger group and thus makes the selection of blockchain paradigm as a mood one. Before associating to one type of blockchain, it is important to fathom about the various categories in blockchain like permissionless or public blockchain and permissioned or private blockchain, hybrid healthcare and consortium blockchain variants in detail, and it is shown in Figure 1.6.

1.3.1 Permissionless or Public Blockchain

Permissionless or public blockchain is a complete decentralized open network as shown in Figure 1.6a. In this type of blockchain network, anyone who wants to be a part of the blockchain network can join the network at any time and can take participate in the transactions, can add, read and write data to the chain and also participate in the consensus using the mining mechanisms. The data in the chain will be maintained by everyone participating in the network, and so it is accessible by all participants in the network. Also, there is no central controlling point, which makes it an authority free network. In this network, once the data are validated by all the participating nodes, then the data become immutable from there as it is maintained by all the nodes participating in the network. The data validation is done based on the Proof of Work (PoW) or Proof of Stake (PoS) consensus algorithms, and each user in the network will be provided with an incentive if they involve themselves in the data validation to make the network more alive and supple.

In the PoW, the users, called miners, are asked to solve a mathematical puzzle, which needs a lot of computational power both in terms of electricity and resources used. In PoS consensus algorithm, the amount of data validation the user can do is directly proportional to the stake value he holds. The data validation will be allocated to the users randomly and the user will be rewarded if the block is added to the blockchain else the user will be fined with the same level of reward he receives. The other types of consensus algorithm are as follows: Tindermint, Proof of Luck (PoL), Proof of Personhood (PoP), Ripple [10, 11] and etc. The user incentives are provided in the name of tokens of two types, namely monetary value tokens and utility tokens where the monetary tokens have exchanged values and the utility token do not have exchanging values but have intrinsic values. The users involved in the blockchain process are anonymous, and only their blockchain address is needed. In public blockchain network, no third-party intervention is needed as it is an open network with no single controlling authority. The public blockchain has its application in digital currencies, public sector like education and healthcare, consumer to consumer, and business to consumer model. Bitcoin, Ethereum, Tezos, and Litecoin are the most popular platforms, which uses the public blockchain networks. The average size of the blocks in Bitcoin is 1.3MB with an average transaction of 285111 per day [12].

Characteristics of Public Blockchain:
There are some unique characteristics for the public blockchain that makes it differ from other types, which are as follows:

- fully decentralized,
- no restrictions to join the network,
- offers anonymity for the users,
- all users can involve in all activities of blockchain,
- no single controlling points,
- complete transparency,
- incentives for the users.

Advantages of Public or Permissionless Blockchain:
Public or permissionless blockchain type comes with a number of advantages in its deployment style. The strong security in this type of blockchain can prevent the skullduggery or the impact made by this activity can be reduced because of the large volume of the users in the network. The public blockchain network will be propelled by providing the incentives to its users.

Disadvantages of Public or Permissionless Blockchain:
The main disadvantage of public or permissionless blockchain type is its complete transparency, which leads to the lack of privacy. This type of blockchain is slow in operation, and thus, the number of transactions for the given time is very limited. Bitcoin can take 10 minutes to create a block in the chain. Energy consumption will be more because of the maintenance of distributed ledger. The energy consumed by the bitcoin in 2019 July is equal to that of the power consumption of Switzerland. The network can be more vulnerable if a small part of the user behaves maliciously, and this type of blockchain has a risk of around 51% of the total attack in the blockchain. The user when using the PoW needs high computational infrastructure resources, like application specific integrated circuit (ASIC) or graphics processing units (GPU), which are expensive. The size of the block is limited because of the need of large computational resources.

1.3.2 Permissioned or Private Blockchain

The hefty attacks and the openness of the information in the public blockchain have made a path to the more private and secured category of blockchain named private or permissioned blockchain [13, 14] as shown in Figure 1.6b. A private or permissioned blockchain is a network with preselected participants based on the digital signatures as a validating element and controlled by a single authority or governing body within an organization. Not all the users are provided with the access to read, write, or validate the data which prevent data leakage. Different levels of access control will be maintained for the user group by the authority body to maintain the transaction speed and privacy. Private blockchain cannot offer the same level of decentralization provided by the public blockchain, thus it is more centralized as they are controlled by a single authority. Anonymity of the users is not allowed, and every user needs to authenticate him using a valid identity. The immutable of the blocks can be broken by the governing body, thus the data in the blockchain can be modified [15]. It is easy to get the consent from the small group of participants when compared with that of a public blockchain. This type of blockchain is more scalable and saves a lot resource and avoids useless resource usage. It is more robust in nature and has very efficient architecture.

The data can be encrypted based on the commercial needs. The number of computational resources needed will be less, and less time is required to get a consensus among the users because of the limited users in the network. The different consensus algorithms used in the private blockchain are Proof of Authority (PoA), Raft, Proof of Elapsed Time (PoET), Practical Byzantine Fault Tolerance (PBFT), Delegated PoS (DPoS), and so

many other algorithms. The users are not provided with any incentives for validating the data block [16, 17]. Private blockchain finds its application in financial services, retails, healthcare, and supply chain management and in business-to-business model. IBM's Hyperledger [18] Fabric and Ripple are the best examples of private blockchain. Other private blockchain are EOS, R3 Corda, Monax, and Multichain.

Characteristics of Private Blockchain:
The private blockchain has its unique characteristics, which makes it differ from other types of blockchain, are as follows:

- highly secured,
- faster transactions,
- renowned users with restricted access,
- centralized control,
- economical,
- efficient,
- scalable,
- robust architecture.

Advantages of Private or Permissioned Blockchain:
The private blockchain comes with a spare of advantages, which makes it utilitarian type among the distinctive organizations. In a private blockchain network, only authenticated users can participate, and thus, the security and privacy of the data in the block are increased. Each private blockchain network will function based on certain regulations guided by the governing authority. The amount needs to complete a transaction, which will be lesser when compared with the public blockchain. Limited resource usage and the speed of transaction processing with scalability features make the private blockchain best suited for many environments [19].
Disadvantages of Private or Permissioned Blockchain:
On the side, the private blockchain has handful of disadvantages to it. Because of the limited number of users in the private blockchain network, it is easy that the malicious attacker can take control of the network. Thus, the security of the private blockchain is in mood. Private blockchains have trust issues in the network among the users. The information in the block can be modified by the authority person. As it is more centralized, unavailability of the system is possible. The private blockchain will not grow as it is more toward private network with limited users.

Both the public and private blockchains can be either open or closed network based on how the users of these networks access the data in the

blockchain. Four different characteristics can be formed by using their combination as follows:

1. public and open,
2. public and closed,
3. private and open,
4. private and closed.

Public and Open:
This characteristic is related to the normal public blockchain type where all the users with the computational resources can join the blockchain network, and all have the access to read, write, and validate the block in the blockchain. No one will be the controlling authority for this type of network. It is mainly suitable in crypto currencies, like Bitcoin, Ethereum, and Litecoin, in games.
Public and Closed:
In this type, any user can join the blockchain network, but only few users will be providing the access to read the data from the blockchain. A company named "FollowMyVote" is currently designing a blockchain technology, which can be implemented in the election, where everyone can participate in the voting process, but only certain users have the rights to read the voting [20] count. It can also be used in medical and financial organizations where the need of securing the data is very important.
Private and Open:
In private and opened model, only the invited user can participate in the blockchain network where certain user can write the data into the block and the others can read and consume the data from the block. A use case for this type of blockchain is the supply chain management in which only the manufacturer will add the information to the blockchain, and all other parties involved can access the data in the blockchain.
Private and Closed:
Private and closed type of blockchain is also known as private blockchain or permissioned blockchain. In which, only trusted users are allowed in the network to participate in blockchain activities with different level of access control. Private and closed blockchain is used in insurance industries, DHL is using it for its logistics management, and Walmart is using this technology for its supply chain management.

1.3.3 Consortium Blockchain

The openness of the public blockchain and the centralization of the private blockchain led to a new category of blockchain known as consortium

blockchain or federated blockchain, where multiple organizations will participate in the network and have the authority over the blockchain whereas in private blockchain only one organization will have the authority. As per Figure 1.6c, the users of the network are culled identified users who can read, write, and audit the data in the blockchain network. All the users have the equal access control on the data in the blockchain. It is a decentralized network where the consensus process involves all the organizations involved in the blockchain. In this blockchain, the immutable of the data is preserved as no single organization controls the blockchain. Every organization will maintain individual copy of the record of data and any modification can be easily identified and proved in the blockchain network. No incentives are provided for the users in the network for the data audit or validation. The consensus algorithm used in consortium blockchain is Proof of Trust (PoT) and Proof of Vote (PoV) and these algorithms need very limited resources and the transactions are speedy. In PoT, the validators are selected based on their trust value and in PoV the validators will consensus based on the voting mechanisms. Consortium blockchain is mainly used in financial sectors followed by logistics, healthcare and cross sectors. Quorum, Hyperledger, and Corda are the well-known examples of consortium blockchain. The performance of this blockchain is around 1000 to 2000 transactions per second.

Characteristics of Consortium Blockchain:

Consortium blockchain has bulged itself from other blockchain in various industries where the organization needs to collaborate among them based on its unique characteristics. The characteristics of consortium blockchain are as follows:

- decentralized nature,
- renowned users with equal access rights,
- faster transactions,
- limited resource need,
- scalability,
- high security,
- immutable nature of data.

Advantages of Consortium Blockchain:

The consortium blockchain head start with splashy advantages in the field of blockchain. Consortium blockchain is a private blockchain but with decentralized control on the network. Because of the limited authenticated users in the network, it is free from malicious activities and uses constricted