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An Overview of Blockchain

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ABSTRACT

With the rise of digital currency in recent years, its underlying technology, blockchain, has become increasingly popular. Blockchain is a decentralized digital ledger that securely stores records across a network of computers in a way that is transparent, immutable, and resistant to tampering. Blockchain is one of the most disruptive technologies since the Internet was invented. As a disruptive technology, blockchain has become a strategic priority for many businesses. The trust issues with the existing technologies inspired practitioners and governments to focus on alternative options such as blockchain. In this paper, we will go over how blockchain works, what benefits it provides, and some of its potential applications.

KEYWORDS: *blockchain, distributed digital ledger, overview of blockchain*

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INTRODUCTION

The 21st century is all about technology. With the increasing need for modernization in our day-to-day lives, people are open to accepting new technologies. Technologies like artificial intelligence and IoT that have gained pace in the past decade and now there is a new addition to the pack, i.e. blockchain technology.

Blockchain technology is a shared database or ledger that allows transparent information sharing within a business network. Traditional database technologies present several challenges for recording financial transactions. To avoid potential legal issues, a trusted third party has to supervise and validate transactions. Blockchain mitigates such issues by creating a decentralized, tamper-proof system to record transactions. The key difference between a traditional database or spreadsheet and a blockchain is how the data is structured and accessed. A blockchain is a series of blocks of data which are linked to each other via cryptographic hash functions. Each of these blocks contains data that is secured cryptographically, which makes it resistant to modification. Blocks are linked in a chronological "chain" and each network node has a replica of the entire database. These blocks are linked using cryptography. *Blockchain* owes its name to the way it stores transaction data—in *blocks* linked together to form a *chain*.

WHAT IS BLOCKCHAIN?

Blockchain, a type of distributed digital ledger technology (DLT), is a relatively new and exciting way of recording transactions in the digital age. It is a decentralized and distributed digital ledger technology that securely records and verifies transactions across multiple computers or nodes in a network. Basically, it is a chain of blocks in which each block contains a list of transactions. The symbol of a blockchain is depicted in Figure 1 [1].The blockchain technology was created as the foundational basis for Bitcoin – a digital currency in which secure peer-to-peer transactions occur over the Internet. It is expected that the spending on blockchain solutions worldwide would grow from 4.5 billion USD (2020) to an estimated value of 19 billion USD by 2024 [2].

Originally developed as the accounting method for the virtual currency Bitcoin, blockchains are

appearing in a variety of commercial applications today. Blockchain technology is a type of distributed digital ledger that uses encryption to make entries permanent and tamper-proof and can be programmed to record financial transactions. It is used for secure transfer of money, assets, and information via a computer network such as the Internet without requiring a third-party intermediary. It is now being adopted across financial and non-financial sectors. As a catalyst for change, the blockchain technology is going to change the business world and financial matters in major ways. The key characteristics of blockchain are displayed in Figure 2 [3].

Blockchain is a combination of three leading technologies [4,5]:

1. *Cryptographic keys* which consist of two keys – Private key and Public key. These keys help in performing successful transactions between two parties. Cryptography is a technique of securing communication by converting plain text into unintelligible ciphertext. It plays a fundamental role in ensuring the security and integrity of blockchain technology.
2. *A peer-to-peer network* with every node having a copy of the ledger. This is a network structure where any participant in the network known as a node acts as both a client and a server. Interconnected nodes ("peers") share resources among each other without the use of a centralized administrative system. New transactions must be confirmed by a predetermined number of computer nodes.
3. *Consensus algorithm* is a process used to achieve agreement on a single data value among distributed processes or systems. Consensus algorithms are designed to achieve reliability in a network involving multiple unreliable nodes. In a blockchain system, each node stores a complete record of all transactions in a database.

Blockchain combines existing technologies such as distributed digital ledgers, encryption, immutable records management, asset tokenization and decentralized governance to capture and record information that participants in a network need to interact and transact. As illustrated in Figure 3, a complete blockchain incorporates all the following five elements [6]:

- *Distribution:* Digital assets are distributed, not copied or transferred. A protocol establishes a set of rules in the form of distributed mathematical computations that ensures the integrity of the data exchanged among a large number of computing devises without going though a trusted third party. A centralized architecture presents several issues including a single point of failure and problems of scalability.
- *Encryption:* BC uses technologies such as public and private keys to record data securely and semi-anonymously. Completed transactions are cryptographically signed, time-stamped, and sequentially added to the ledger.
- *Immutability:* Immutability means something cannot be changed, altered, or deleted. No participant can tamper with a transaction once someone has recorded it to the shared ledger. The data stored on the blockchain is secured via cryptographic hash functions and thus cannot be tampered with. Blockchain lacks the capability to modify or delete data once it is recorded. No entity can modify the transaction records. Thus, Blockchains are secure and meddle-free by design. Data can be distributed, but not copied.
- *Tokenization:* Tokenization is the process of creating a digital representation of an asset or commodity on the blockchain. Tokens can represent anything from stocks and bonds to *real estate* and artwork. Value is exchanged in the form of tokens, which can represent a wide variety of asset types, including monetary assets, units of data or user identities.
- *Decentralization*: Decentralization is a key feature of blockchain technology, which refers to the distribution of power and decision-making across a network of nodes or participants rather than being controlled by a central authority or system. All the data inside the blockchain is not owned by a single centralized entity. Rather, the nodes, which are the people who help manage the network, all download the blockchain data onto their computers, which means that no one party owns the data. Decentralization in blockchain refers to transferring control and decision making from a centralized entity (individual, organization, or group) to a distributed network. No single entity controls a majority of the nodes or dictates the rules. A consensus mechanism verifies and approves transactions, eliminating the need for a central intermediary to govern the network. Figure 4 shows the decentralized property of blockchain [7].

Blockchain became famous when it was used to develop the most popular cryptocurrency, Bitcoin. Bitcoin's status as digital gold is merely the tip of this technology. Cryptocurrencies like Bitcoin, Ethereum, and Litecoin are mentioned as interchangeable with blockchain. Figure 5 shows Bitcoin [8], while Figure

6 shows how blockchain works [9]. Although blockchain technology will for all time be associated with Bitcoin due to their common genesis, it has broader applications.

A blockchain is a tamper-proof, distributed database that stores blocks of information for cryptographically bound transactions via peer-to-peer networks. At the heart of blockchain's functionality is cryptographic hashing. Each block in a blockchain contains a cryptographic hash of the previous block, creating an immutable chain of blocks. If anyone attempts to tamper with the data in a block, it would alter the block's hash. This would disrupt the entire chain, making it virtually impossible to manipulate. The security feature ensures data integrity and prevents unauthorized changes [10].

In a nutshell, blockchain technology involves three basic concepts [11]: (1) It is a system for recording a series of data items (such as transactions between parties); (2) It uses cryptography to make it difficult to tamper with past entries; (3) It has an agreed process for storing copies of the ledger and adding new entries (also called a consensus protocol).

BRIEF HISTORY OF BLOCKCHAIN

Blockchain technology has its roots in the late 1970s when a computer scientist named Ralph Merkle patented Hash trees or Merkle trees. In the late 1990s, Stuart Haber and W. Scott Stornetta used Merkle trees to implement a system in which document timestamps could not be tampered with. This was the first use of blockchain. The technology has continued to evolve over these three generations [12]:

- *First generation – Bitcoin and other virtual currencies:* In 2008, an anonymous individual or group of individuals known only by the name Satoshi Nakamoto outlined blockchain technology in its modern form. Satoshi's idea of the Bitcoin blockchain used 1 MB blocks of information for Bitcoin transactions. Many of the features of Bitcoin blockchain systems remain central to blockchain technology even today. Bitcoin is the first decentralized digital currency to enable peer-to-peer transactions without a central authority. Since Bitcoin was an early application of blockchain technology, people inadvertently began using Bitcoin to mean blockchain, creating a misnomer.
- *Second generation – smart contracts:* A few years after first-generation currencies emerged, developers began to consider blockchain applications beyond cryptocurrency. For instance, the inventors of Ethereum decided to use blockchain technology in asset transfer transactions. Their significant contribution was the smart contracts feature.
- *Third generation – the future:* As companies discover and implement new applications, blockchain technology continues to evolve and grow. Potential opportunities are limitless in the ongoing blockchain revolution.

TYPES OF BLOCKCHAIN

There are several ways to build a blockchain network. Blockchains fall into three general categories — public, private, and consortium blockchains. They are illustrated in Figure 7 [13] and explained as follows [14]:

- *Public Blockchains:* These are also called "permissionless" blockchains. Public blockchains are open to the public, and anyone can access and participate in these networks without anyone's permission. These include Bitcoin, Ethereum, Litecoin, and many other cryptocurrencies. People primarily use public blockchains to exchange and mine cryptocurrencies like Bitcoin, Ethereum, and Litecoin. The main advantage of public blockchains is that it is simple to join their network since it is open to whomever wants to participate, provided that the rules of the network are followed. Public blockchains are decentralized and transparent; there is no one central body controlling the data on the blockchain. Many public blockchains suffer from scalability issues. For example, Bitcoin can only manage somewhere between 3–7 transactions per second, and it takes 10 minutes to mine a block. This is not good enough for big enterprises who need to deal with millions of transactions per day with near zero latency.
- *Private Blockchains:* These are also known as permissioned or managed blockchains. They are controlled by a central authority and only allow a select few to take part in the network. Members of private blockchains need permission to participate. Because the number of nodes are limited in private blockchains, consensus can be reached very quickly. Thus transactions can be executed faster and the system can be scaled more easily. Since no random person can enter the network and become a participant, privacy is increased. For example, Walmart, the world's largest retailer, is working with IBM to use blockchain to track the source of their vegetables throughout the supply chain. Ripple, a digital currency exchange network for businesses, is another example of a private blockchain.

- *Consortium Blockchains:* A consortium blockchain is a hybrid blockchain. It combines elements from both private and public networks. Consortium blockchains follow a permission system called shared permissioned ledgers. Instead of allowing anybody to participate in the blockchain (as in public blockchains) or having one entity primarily control the network (as in private blockchains), a small number of entities are selected to manage the network. The right to read the blockchain may be public, but the ability to form consensus and edit the network data is restricted only to the participants. Consensus is a dynamic way of reaching agreement in a group. For example, hybrid blockchains can grant public access to digital currency while keeping bank-owned currency private.

APPLICATIONS OF BLOCKCHAIN

Blockchain has numerous uses besides keeping track of monetary transactions like those involving Bitcoin. It has numerous applications to improve efficiency, accuracy, and sustainability. It plays a crucial role across industries such as agriculture, healthcare, supply chain, finance, accounting, energy, food safety, commerce, and media and entertainment. Some of these applications are shown in Figure 8 [15] and are explained as follows [11,16]:

- *Energy:* The energy industry is undergoing a shift towards a clean and distributed approach in response to the energy revolution and environmental protection movement. Energy companies use blockchain technology to create peer-to-peer energy trading platforms and streamline access to renewable energy. Blockchain-based energy companies have created a trading platform for the sale of electricity between individuals. Homeowners with solar panels use this platform to sell their excess solar energy to neighbors. The process is largely automated: smart meters create transactions, and blockchain records them. Figure 9 shows an implementation of blockchain in the energy sector [17].
- *Finance:* Financial service providers find blockchain technology useful to enhance authenticity, security, and risk management. Blockchains have been heralded as a disruptive force in the finance sector, especially with the functions of payments and banking. Traditional financial systems, like banks and stock exchanges, use blockchain services to manage online payments, accounts, and market trading. For example, Singapore Exchange Limited, an investment holding company that provides financial trading services throughout Asia, uses blockchain technology to build a more efficient interbank payment account. Perhaps no industry stands to benefit from integrating blockchain into its business operations more than personal banking. Unlike banks, blockchain never sleeps. Transactions can take place any time, regardless of holidays or the time of day or week. Banking with blockchain technology is depicted in Figure 10 [18].
- *Media and Entertainment:* Companies in media and entertainment use blockchain systems to manage copyright data. Copyright verification is critical for the fair compensation of artists. It takes multiple transactions to record the sale or transfer of copyright content. Sony Music Entertainment Japan uses blockchain services to make digital rights management more efficient. They have successfully used blockchain strategy to improve productivity and reduce costs in copyright processing.
- *Retail:* Retail companies use blockchain to track the movement of goods between suppliers and buyers. For example, Amazon retail has filed a patent for a distributed ledger technology system that will use blockchain technology to verify that all goods sold on the platform are authentic.
- *Smart Contracts:* A smart contract is computer code that can be built into the blockchain to facilitate transactions. It operates under a set of conditions to which users agree. When those conditions are met, the smart contract conducts the transaction for the users. Companies use smart contracts to self-manage business contracts without the need for an assisting third party. They are programs stored on the blockchain system that run automatically when predetermined conditions are met. They run if-then checks so that transactions can be completed confidently. For example, a logistics company can have a smart contract that automatically makes payment once goods have arrived at the port. Figure 11 displays the concept of smart contract [18].
- *Voting:* If we store personal identity information on a blockchain, it brings us closer to the possibility of using blockchain for voting. Blockchain could facilitate a modern voting system. Voting with blockchain carries the potential to eliminate election fraud and boost voter turnout, as was tested in the November 2018 midterm elections in West Virginia. Using blockchain in this way would make votes nearly impossible to tamper with. The blockchain protocol would also maintain transparency in the

electoral process, reducing the personnel needed to conduct an election and providing officials with nearly instant results. This would eliminate the need for recounts or any real concern that fraud might threaten the election.

- *Blockchain-as-a-Service (BaaS):* This is a managed blockchain service that a third party provides in the cloud. You can develop blockchain applications and digital services while the cloud provider supplies the infrastructure and blockchain building tools.
- *Healthcare:* One of the primary applications of blockchain in healthcare is electronic medical records (EMRs) management. Healthcare providers can leverage blockchain to store their patients' medical records securely. When a medical record is generated and signed, it can be written into the blockchain, which provides patients with proof and confidence that the record cannot be changed. These personal health records could be encoded and stored on the blockchain with a private key so that they are only accessible to specific individuals, thereby ensuring privacy. Healthcare payers and providers are using blockchain to manage clinical trials data and electronic medical records while maintaining regulatory compliance. Figure 12 shows healthcare blockchain [19].
- *Digital Identity*: The need of the hour is to have a system that manages individual identification on the web. With the rapid development of the Internet, digital identity is becoming increasingly prevalent in various industries. Generally, digital identity enables the association of a person's stored computer information with their societal identity. Broadly speaking, a digital identity is used to identify an individual's presence in an Internet scenario and is a combination of relevant characteristics. Individuals can control their identity securely, reducing the risk of identity theft. Blockchain technologies make tracking and managing digital identities efficient and secure resulting in less fraudulent incidents.

BENEFITS

The key benefit of blockchain lies in its ability to provide security, transparency, and trust without relying on traditional intermediaries, such as banks or other third parties. Perhaps the most profound facet of blockchain and cryptocurrency is the ability for anyone, regardless of ethnicity, gender, location, or cultural background, to use it. Other benefits include the following [12,14]:

- *Automation:* Blockchain is programmable and can generate systematic actions, events, and payments automatically when the trigger criteria are met. Smart contracts facilitate the seamless automation of transactions, enhancing efficiency and accelerating real-time processes. Once predefined conditions are met, they automatically trigger the next step, reducing the need for manual intervention.
- *Less Human Error:* The design of blockchain reduces the risk of fraud and human errors. Transactions on the blockchain network are approved by thousands of computers and devices. This removes almost all people from the verification process, resulting in less human error and an accurate record of information. Even if a computer on the network were to make a computational mistake, the error would only be made to one copy of the blockchain and not be accepted by the rest of the network. By spreading that information across a network, rather than storing it in one central database, blockchain becomes significantly more difficult to tamper with.
- *Cost Reductions:* Typically, consumers pay a bank to verify a transaction or a notary to sign a document. Blockchain eliminates the need for third-party verification and their associated costs. For example, business owners incur a small fee when they accept credit card payments because banks and payment-processing companies have to process those transactions. Bitcoin, on the other hand, does not have a central authority and has limited transaction fees. Goods are costlier than they need to be because middlemen add fees and charges. With blockchain, these intermediaries are kept to a minimum because of the trustlessness of the network, thus reducing costs.
- *Time Savings:* Blockchain slashes transaction times from days to minutes. Transaction settlement is faster because it does not require verification by a central authority.
- *Transparency:* Many blockchains are entirely open source. This means that everyone can view its code. The nodes that have downloaded the blockchain onto their computers can see all the data that is stored on blockchain. Every single bit of data can be traced right back to its very origins. For example, in the Bitcoin blockchain, every single bitcoin (or fraction of a bitcoin) can be traced back to see who owned the currency in the past and what transactions those coins were involved in.
- *Greater Trust:* You no longer have to trust a central party to execute a transaction. The

decentralized nature of blockchains allows peer-to-peer transactions to be carried out without a single party sitting in the middle. Blockchain's transparency lets everyone see that these transactions were executed. Blockchain creates a secure, members-only network, ensuring accurate and timely data access. Confidential records are shared only with authorized network members, fostering trust and creating end-to-end visibility across the system.

- *Better Traceability:* Traceability ensures that the transactions made are traceable. Blockchain offers instant traceability with a transparent audit trail of an asset's journey. Transactions on the blockchain are tracked in chronological order and cannot be changed or reversed due to the cryptographic hashing. All of the network's nodes have access to every transaction, which makes it very easy to trace what transactions took place, when, and by whom.
- *Censorship Resistance:* If a central party manages a network's data, it has the ability to censor how you use their app. For instance, PayPal has a history of not allowing pornography workers to use its payment system.
- *Increased Speed:* Blockchain is increasingly replacing slow, paper-based processes, as well as processes that require alignment of multiple separate databases. By aggregating data on a single distributed ledger, transactions can be executed and shared more efficiently, leading to faster operations in many cases.
- *Secure Transaction:* Blockchain technology achieves decentralized security and trust in several ways. Blockchain systems provide the high level of security and trust that modern digital transactions require. The combination of distributed data and cryptographic hashing makes blockchains more difficult to hack than centralized databases. Hackers no longer have a single database to attack. Rather, they will have to find a way to overcome the security provided by thousands of computers across the world who are monitoring the network. Blockchain uses the three principles of cryptography, decentralization, and consensus to create a highly secure underlying software system that is nearly impossible to tamper with. There is no single point of failure, and a single user cannot change the transaction records.
- *Increased Efficiency:* With a distributed ledger shared among network members, the need for time-consuming record reconciliations is eliminated. Smart contracts, which are stored on the blockchain, can automate processes and speed up transactions. Business-to-business transactions can take a lot of time and create operational bottlenecks, especially when compliance and third-party regulatory bodies are involved. Transparency and smart contracts in blockchain make such business transactions faster and more efficient.
- *Faster Auditing:* Enterprises must be able to securely generate, exchange, archive, and reconstruct e-transactions in an auditable manner. Blockchain records are chronologically immutable, which means that all records are always ordered by time. This data transparency makes audit processing much faster.
- *Decentralized System:* Decentralization is the key feature of blockchain technology. In a decentralized blockchain, no single central authority can control the network. Conventionally, transactions require the approval of regulatory authorities like a government or bank; however, with Blockchain, transactions are done with the mutual consensus of users, resulting in smoother, safer, and faster transactions. Blockchain's decentralized nature helps eliminate the need for intermediaries, reduce costs, and increase efficiency.
- *Finality:* Finality refers to the irreversible confirmation of transactions in a blockchain. If and when a transaction is added to a block, and the network confirms the block, it becomes immutable and cannot be reversed. This feature ensures the integrity of the data and prevents double spending, providing a high level of security and trust.
- *Openness:* Openness in blockchain technology makes the blockchain accessible to anyone who intends to participate in the network. This implies that it is open for all, and anyone can join the network, validate transactions, and add new blocks to the blockchain, so long as they know the consensus rules. Openness promotes inclusivity, transparency, and innovation, allowing participation from various stakeholders.
- *Inclusion:* Blockchain technology can expand the access and availability of lending to the unbanked and underbanked populations, who may lack the formal identification, documentation, or credit history required by the traditional lending institutions.

CHALLENGES

Blockchain technology is often seen as a "cure-all" that can solve a wide range of problems because of its decentralized nature. However, blockchain is not an individual system but rather a protocol that allows different participants to transmit information by synchronizing various databases. The challenges associated with blockchain adoption include regulatory uncertainties, sustainability concerns, and the emerging need for skilled professionals. An issue with many blockchains is that each block can only hold so much data. The block size debate has been and continues to be one of the most pressing issues for the scalability of blockchains in the future. Other challenges include [20]:

- *High Cost:* Although blockchain can save users money on transaction fees, the technology is far from free. The adoption of blockchain technology entails significant financial investments, making it a capital-intensive endeavor for most companies. This financial barrier serves as a deterrent to many enterprises considering the implementation of blockchain solutions. For example, the Bitcoin network's proof-of-work system to validate transactions consumes vast amounts of computational power. Given the scarcity of skilled professionals in this domain, the cost of acquiring such talent can be substantial.
- *Data Inefficiency:* Bitcoin is a perfect case study of the inefficiencies of blockchain. Bitcoin's proof-of-work (PoW) system takes about 10 minutes to add a new block to the blockchain. At that rate, it is estimated that the blockchain network can only manage about seven transactions per second. Although other cryptocurrencies, such as Ethereum, perform better than Bitcoin, the complex structure of blockchain still limits them.
- *Illegal Activity:* While confidentiality on the blockchain network protects users from hacks and preserves privacy, it also allows for illegal trading and activity on the blockchain network. This system gives anyone access to financial accounts, but allows criminals to transact more easily. Many have argued that the good uses of crypto, like banking the unbanked, outweigh the bad uses of cryptocurrency, especially when most illegal activity is still accomplished through untraceable cash.
- *Regulation:* Blockchain technology operates in a largely unregulated and uncertain legal environment, which can pose various challenges and risks for automated lending. Many in the crypto space have expressed concerns about government regulation of cryptocurrencies. Several jurisdictions are tightening control over certain types of crypto and other virtual currencies. However, no regulations have yet been introduced that focus on restricting blockchain uses and development.
- *Data Storage:* Another significant implication of blockchains is that they require storage. This may not appear to be substantial because we already store lots of information and data. Every node stores a complete record of all transactions in a database. This decentralized setup leads to a notable outcome—the transaction database grows rapidly over time. However, as time passes, the growing blockchain use will require more storage, especially on blockchains where nodes store the entire chain. Currently, data storage is centralized in large centers. But if the world transitions to blockchain for every industry and use, its exponentially growing size would require more advanced techniques to make storage more efficient.
- *Interoperability:* The diversity in protocols, algorithms, and data structures across various blockchains hinders seamless information exchange, limiting their potential as universal transaction platforms. Initiatives to foster data transfer between blockchains are emerging, but interoperability remains a significant challenge.
- *Scalability:* Blockchains face scalability issues due to limited transaction throughput. As more transactions occur, scalability becomes crucial. Blockchain technology faces a trade-off between security, decentralization, and scalability. As the number of transactions and users on the blockchain increases, the network becomes more secure and decentralized, but also slower and more expensive.
- *Private Keys*: The security of the blockchain network is primarily upheld by the concept of private keys. These private keys play a crucial role in validating blockchain addresses and ensuring the integrity of transactions. When a user opens a cryptocurrency wallet, they are provided with a unique private key. Losing the private key can be catastrophic, as it renders the user unable to access their funds. To mitigate this risk, it is essential to store multiple copies of the private key securely.
- *Education:* Blockchain is still an emerging technology, so it is hard to understand how it works without looking into the code or getting deep into computer science concepts. It is a

complex and novel concept, which can be difficult to understand and use for the average user. The users need to have a basic knowledge and awareness of how blockchain technology works, what are the benefits and risks, and how to use the tools and platforms available. The blockchain community and industry need to provide more education and support to the users to increase their confidence and competence in using blockchain technology.

CONCLUSION

Blockchain is a shared, immutable digital ledger, enabling the recording of transactions and the tracking of assets within a business network and providing a single source of truth. With many practical applications for the technology already being implemented and explored, blockchain is finally making a name for itself in no small part because of Bitcoin and cryptocurrency. Blockchain technologies are growing at an unprecedented rate and powering new concepts for everything from shared storage to social networks. As we head into the third decade of blockchain, it is no longer a question of if legacy companies will catch on to the technology, it is a question of when.

Blockchain technology revolutionizes trust, transparency, and accountability. It has revolutionized the way we look at transactions and data management. As the digital revolution advances, blockchain technology can help to maintain the balance between technology, user data, and privacy. As blockchain innovation continues to grow and become user-friendly, the onus is on every individual who wants to learn this emerging technology to prepare for the future. More information on the blockchain technology is available from the books in [21-28] and the following related journal: *IEEE Blockchain.*

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Figure 1 The symbol of blockchain [3].

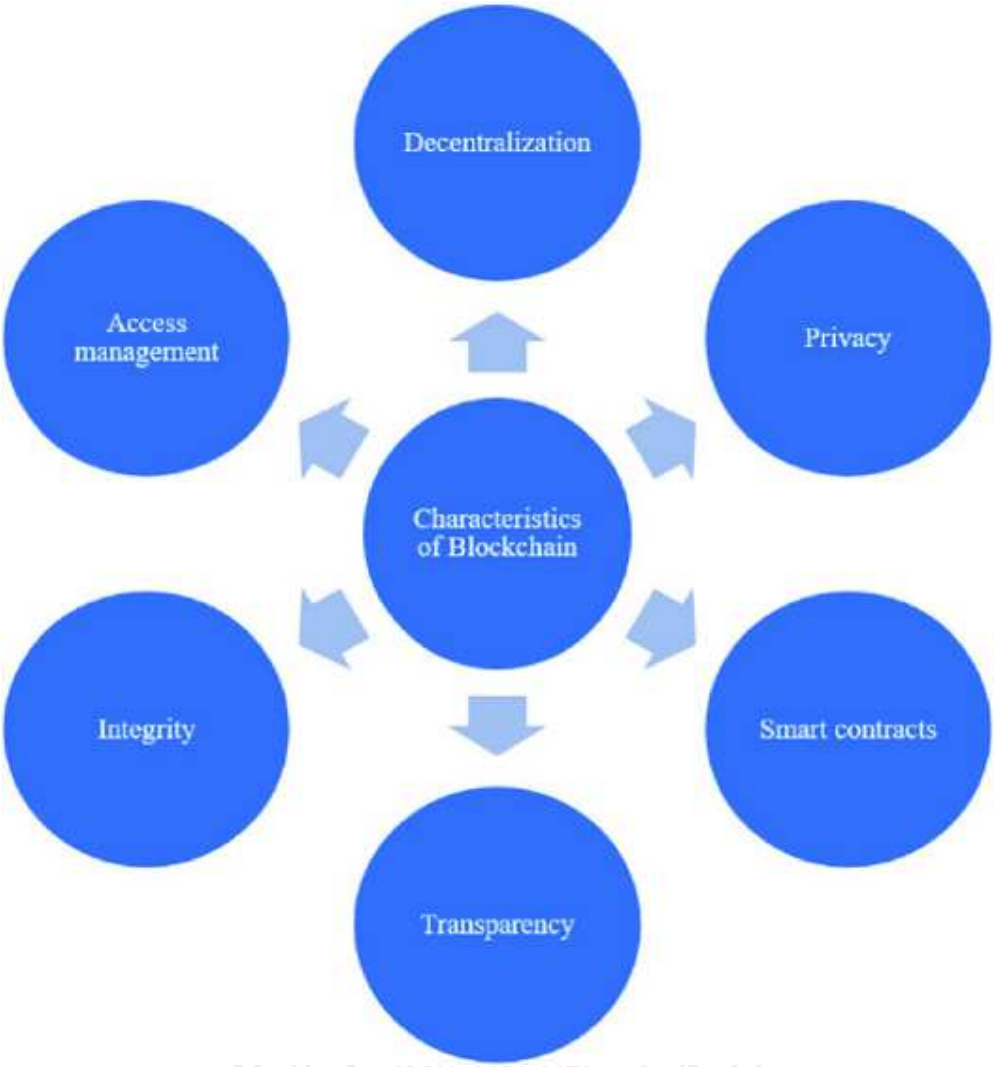

Figure 2 The key characteristics of blockchain [3].

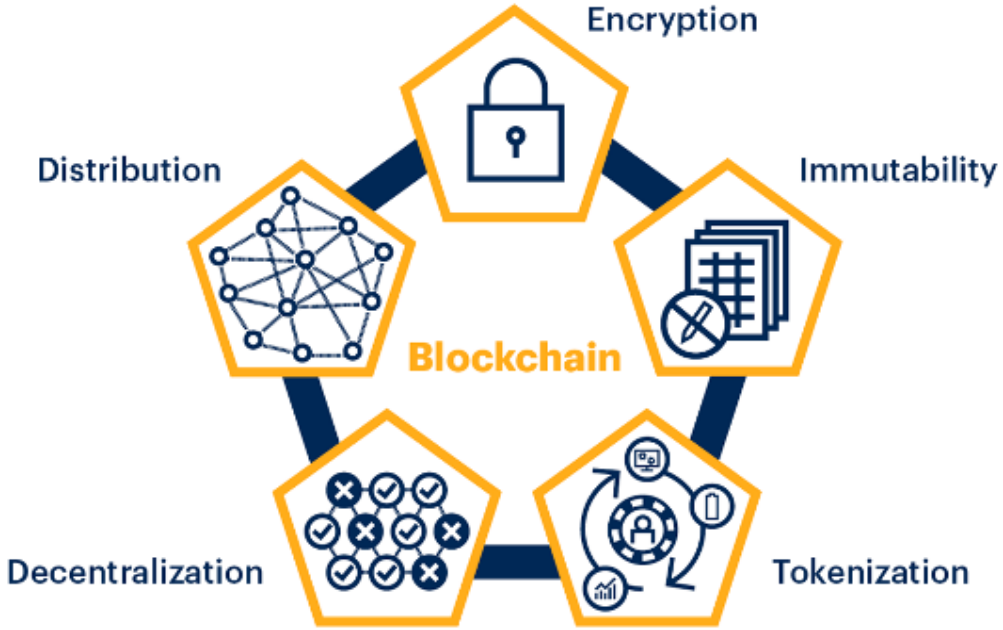

Figure 3 Five key elements of blockchain [6].

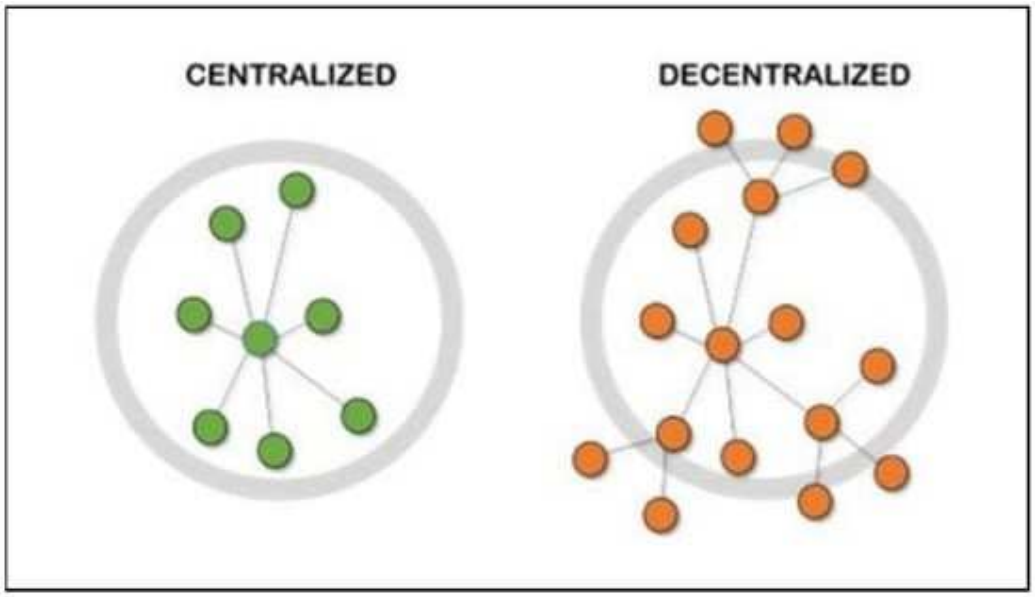

Figure 4 The decentralized property of blockchain [7].

Figure 5 Bitcoin [8].

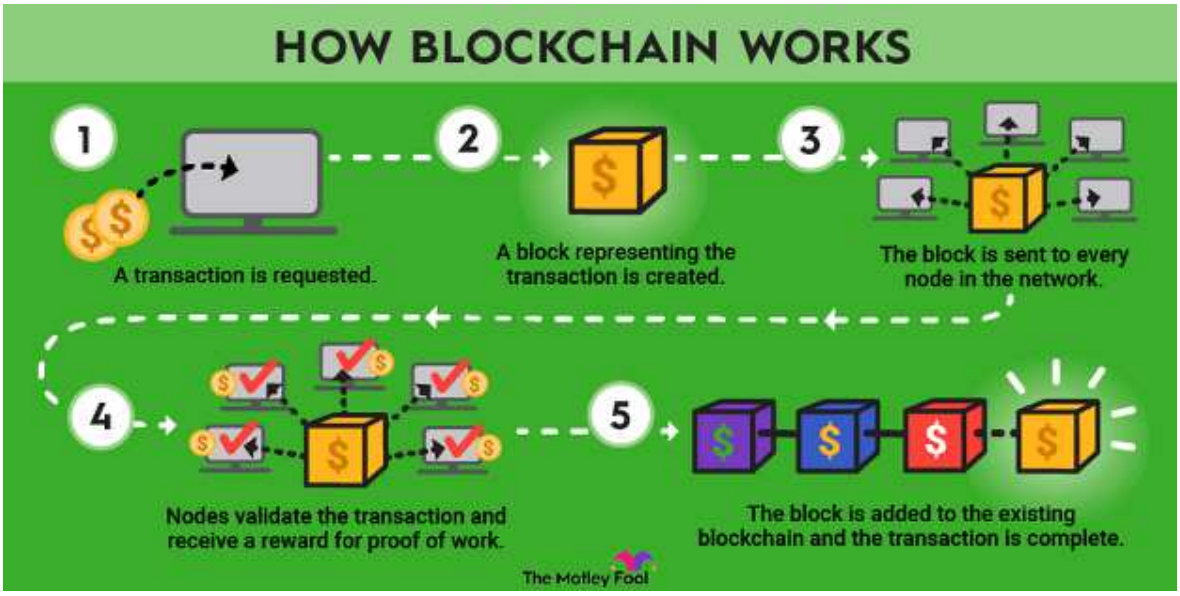

Figure 6 How blockchain works [9].

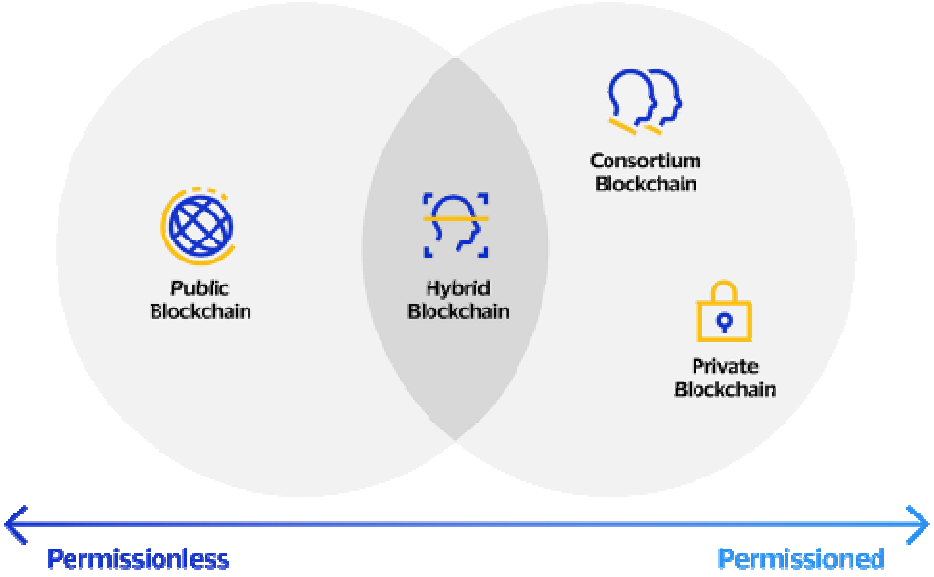

Figure 7 Types of blockchain networks [13].

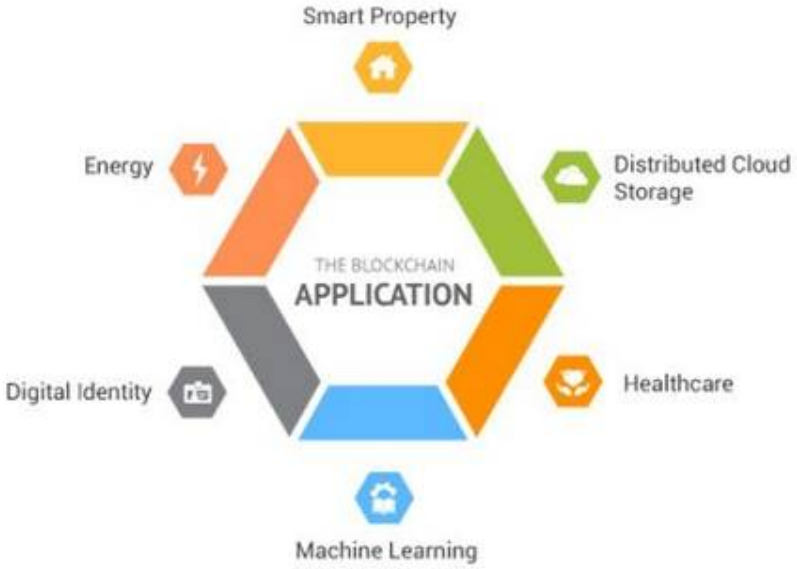

Figure 8 Some of these applications of blockchain [15].

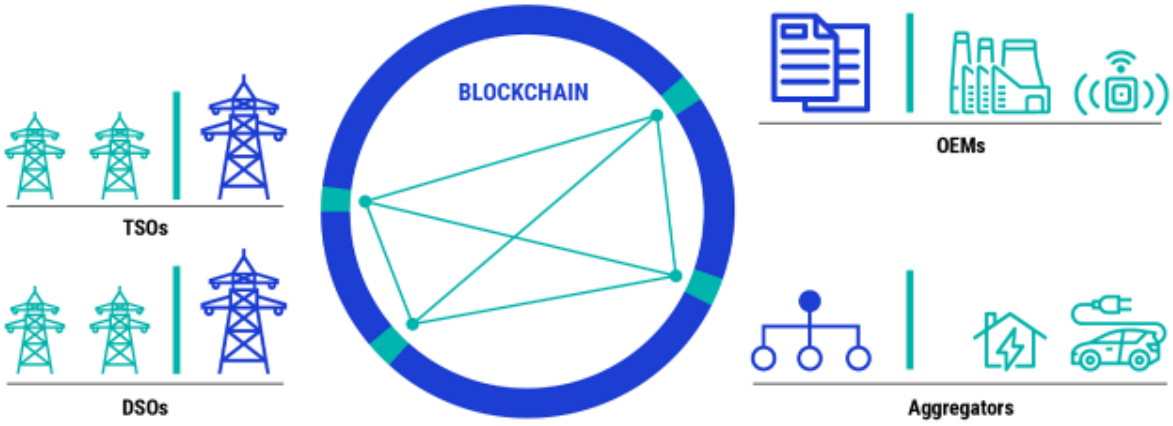

Figure 9 An implementation of blockchain in the energy sector [17].

Figure 10 Banking with blockchain technology [18].

Figure 11 The concept of smart contract [18].

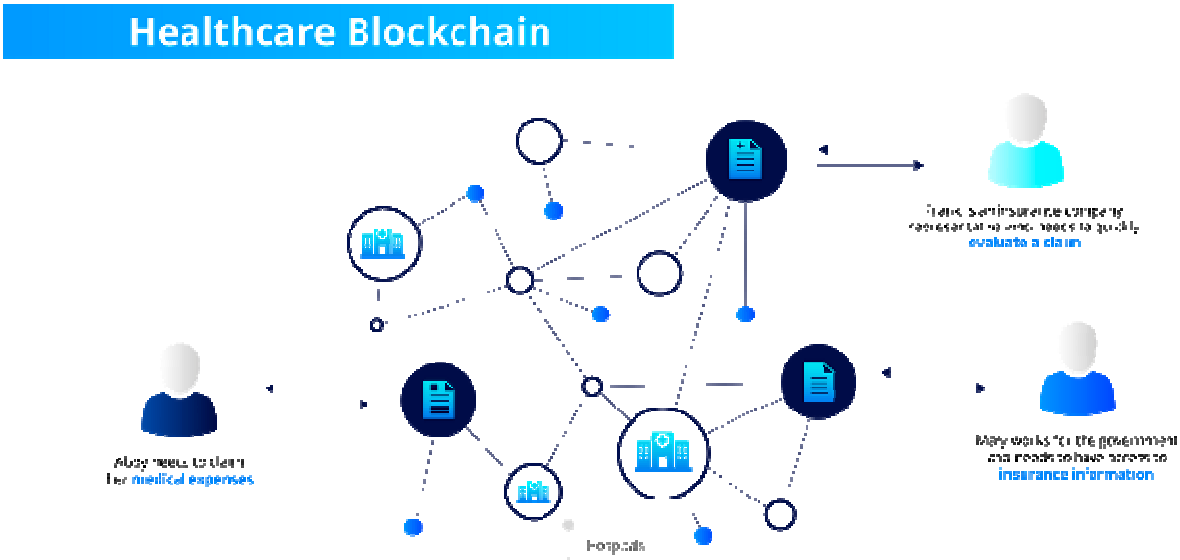

Figure 12 Healthcare blockchain [19].