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The Role of Blockchain Technology in Enhancing Data Integrity and Transparency Across Industries

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***Abstract*:** This technology applies cryptographic and consensus mechanisms that secure communications between participating peers. Each transaction on the blockchain is assigned a timestamp, thus establishing the transaction's historical order and preventing it from being altered. Newer transactions are added to the blockchain only after several participating nodes have approved them. Transactions approved on the same block form a distributed consensus around this block. If such a transaction is modified, the transaction's timestamp would be different from that recorded on the block containing it, and the distributed consensus would no longer hold. The blockchain would increase its size with the addition of subsequent blocks appended to it, making it computationally expensive to modify older transactions. These concerns are further fueled by the potential risk of data leaks or hacks that could occur directly or indirectly through third-party system providers. Many organizations do not fully comprehend how third parties could potentially gain access to sensitive information despite using various cybersecurity methods such as data encryption. Some online platforms contain shared databases that may store data collected by large networks of businesses, which allows them to gain a more thorough profile of an individual. This profiling is alarming consumers and resulting in distrust in how their data is used. There is a growing movement to decide whether personal data should be regarded as personal property instead of a product owned by online platforms. Consumer unrest has resulted in actions such as the General Data Protection Regulation (GDPR), which attempts to diminish online activity surveillance. Blockchain data is typically stored using linked data structures implemented in computer program language using Applications Programming Interfaces (APIs). A frequently used data structure is a Merkle tree, where a binary tree is used to store the information, creating a binary search tree that allows verifying the information with only a small subset of the data.

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***Keywords*:** Applications programming interfaces, Hacks, Blockchain, Cryptographic

1. Introduction

Blockchain technology is a decentralized distributed system based on a consensus from participating nodes working in a peer-to-peer network. Each participating peer node has a complete replicated and consistent copy of the blockchain containing a list of transactions grouped in blocks linked in a chronological order. A consensus agreement between participating nodes must be reached for a block of transactions to be appended to a blockchain. The consensus is usually based on cryptographic protocols employed in the permissionless architecture of public networks such as those operating Bitcoin, Ethereum, Litecoin, and others [1].

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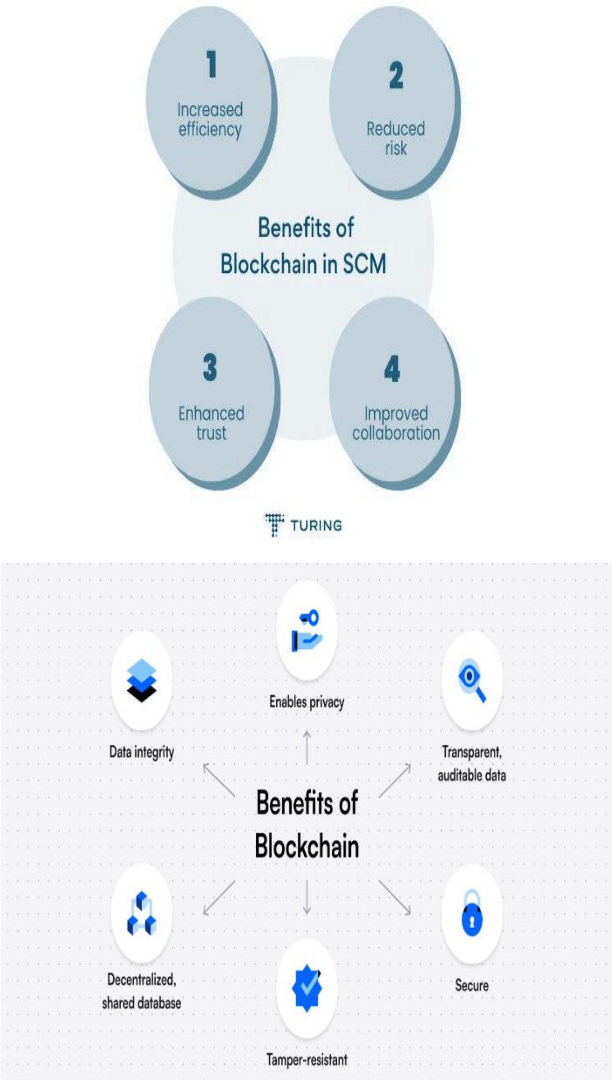

Figure 1. Blockchain identity management

The first blockchain-based public cryptocurrency proposal and implementation were by S. Nakamoto in 2009 with Bitcoin. Following this work, there has been widespread interest in blockchain technology, and it has gained popularity across several disciplines, including finance, supply chain, Internet of Things (IoT), personal health records, smart contracts, and social networking [2].

1.1 Background and Significance

Since the 2000s, there has been a rapid development of web-based applications on various online platforms. Businesses, including retailers and service providers, have begun to collect and store large amounts of user or customer data to improve and grow their activities. Data is essential to businesses, providing them with information necessary for proper formulation of strategies. However, as businesses progress with data collection, usage, and storage, more concerns arise about consumer privacy. There have been complaints about some industries gaining access to sensitive data, such as medical history or bank details, without consumer knowledge. These concerns, alongside previous national scandals concerning privacy breaches, have led to increased scrutiny on how data is processed, shared, and stored [1].

1.2 Research Objectives

The research objectives are specific goals and aims of the essay. This section details the intentions behind exploring the role of blockchain technology in enhancing data integrity and transparency across industries. This overview will also touch on the broader issue of data use and manipulation in more varied domains. This section will serve as a roadmap for the readers to understand the purpose and focus of the research. Blockchain technology has been the subject of intense focus over the past few years as a “disruptive” technology with the potential to realign the established order in many industries. Blockchain and distributed ledger technologies are being heralded as technologies with the potential to enhance data integrity and transparency across a range of industries. In education, where there are significant issues surrounding data ownership, privacy, identity verification, and authentication of documentation, there has been increased interest in this technology [3]. Blockchain technology has its origins in academia and became the basis of the Bitcoin cryptocurrency, first proposed in a paper by Satoshi Nakamoto in 2008, released together with open-source software in 2009. The architecture of the blockchain is designed to share unalterable transaction records across a decentralised network, with mathematics, cryptography, and economic incentives preventing malign manipulation of the database.

2. Understanding Blockchain Technology

Blockchain Technology has transformed the landscape of the Internet since the inception of Bitcoin in 2008. Blockchain is defined as a distributed ledger (or database) that is shared among the nodes of a peer-to-peer computer network. It provides a secure mechanism to store and share data in a decentralised manner.

Table 1. Understanding blockchain technology

Challenges of the Current Healthcare System	Challenges of the Current Healthcare System
Drug counterfeit	Interoperability
Data segmentation	Security
Poor management	Maintenance cost
Healthcare security and data storage	Data integrity Universal access

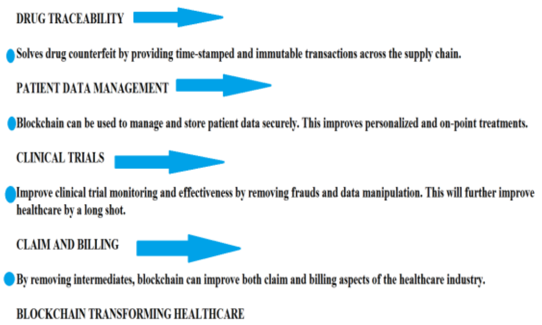

Figure 2. Blockchain technology

Unlike conventional databases that are typically controlled by a central authority (e.g. company, government, organization, etc.), a blockchain is maintained by several nodes, which are responsible for the transactions, and detect and store the same transaction with an identical cryptographic fingerprint. Once a transaction is confirmed occurring and stored in the blockchain, all the current nodes will automatically update their copy of the blockchain, and the transaction becomes immutable [4]. New information can be added to the blockchain but nothing can be modified or erased. Consequently, the blockchain is a chronological and tamper-proof record of all transactions that occurred since its creation.

2.1 Definition and Key Concepts

A blockchain is composed by blocks (or nodes), which consist of three main types of information:

- A set of transactions, which are the data;
- A cryptographic hash of the previous block;
- A nonce, which is a random number used to find the hash of the block, that must have some characteristics to allow it to be accepted by the network [5].

On a basic conceptual level, blockchain technology can be considered as a digitized decentralized ledger containing a chain of blocks (digital records), with security being provided through the use of cryptographic keys [6]. To ensure consistency of the data within the digital ledger, background procedures are employed including, but not limited to, coded algorithms (protocols), peer to peer exchanges of information among different users of the digital ledger, mutual consideration of the records by the members of the network and mechanism of "rewarding" the members involved in the procedure. In procedural terms, blockchain can be defined as a distributed database that is being shared and continuously updated among users having unlimited access to this information. Blockchain can be used as an opportunity to develop new, different, and possibly disruptive business models. Some of the alternative business models and business processes triggered by blockchain are described in the following paragraphs. More specifically, some use cases for different sectors are illustrated, showing "Disintermediated" business models; "Smart contracts" business models; Blockchain as a product. Some sectors or industries are addressed to showcase possible changes: Financial services, Retail, Transport, Industry 4.0, Medicine and healthcare, Smart cities.

Blockchain is a tamper-proof distributed ledger technology. The term "blockchain" refers to a tamper-proof distributed ledger technology. In a blockchain ecosystem, peer nodes share the same database and there is no need for a central internet intermediary to facilitate trust between transacting parties. The database is a shared ledger of transactions, and users can write new transactions stored on the database as blocks. The blocks are cryptographically linked by hashing and time-stamped data. Thus, the transaction history is imprinted on the blockchain as an immutable series of data. Each peer node in the network stores a copy of the database and runs the same consensus mechanism to make sure that the copies of the database on every node are the same.

2.2 How Blockchain Works

The technology behind blockchain allows for a distributed database that is open to anyone or everyone but can only be changed with the consensus of all parties involved. It is essentially a ledger that can hold transaction information and be stored on multiple computers. This type of ledger is commonly used for money exchanges and other events that need to be tracked. The ledger holds the information in blocks of digital data with a concluding cryptographic checksum-hash-to make sure all the data inside of that block has not been altered and to prevent future tampering [4]. Each block is chronologically linked to the previous block, creating on a chain of blocks-blockchain-with a unique hash. Adding information to this blockchain is done through hashing. When a transaction occurs, it is validated. The validation involves a proof of work (PoW) process that attempts to solve an arbitrary mathematical problem. This problem includes the block's hash and the hashes of the previous blocks. This part of the process is computationally intensive, which protects the ledger from aggressive overhauls by any malicious party. Once the block and the mathematical problem are completed, they are sent to all computers involved in the blockchain. If all the computers agree upon the solution-with a consensus of at least 51%-the new block is added to the chain and distributed to all units. This verification method creates a second layer of safety on top of the use of hash codes and an accumulation of security.

Because of the satisfying attributes of blockchain technology, applications for the technology have moved far beyond the banking sector. Figure 3 was illustrated exploring using blockchain technology to store property exchange records. Chinese manufacturing companies have begun to consider using blockchain technology to enhance supply chain management. In Ecuador, the government is looking into using the technology on land registrations and transactions. In the quality food sector, retailers are experimenting with the technology to create safety and tracking systems. The desire to pursue blockchain technology beyond financial purposes mainly comes from society's need for trust. Institutions need to be established so that all the parties involved in a transaction trust one another, and that is what makes them costly and time-consuming.

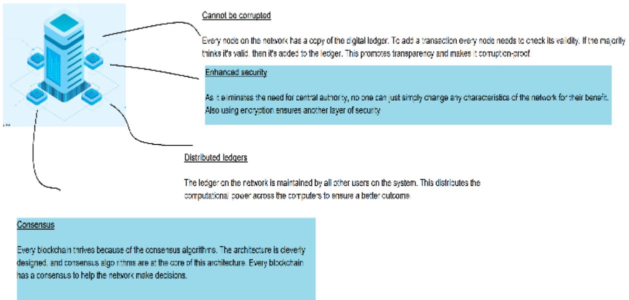

Figure 3. Key features of blockchain technology

3. Applications of Blockchain Technology

The applications of blockchain technology are vast and can be seen practically across various industries, including supply chain management, healthcare, finance, and banking. By highlighting these specific applications, the use of blockchain technology in different industries can be better understood.

Within the supply chain, blockchain technology allows for the sharing of crucial data while enhancing security and privacy. All supply chain participants gain access to necessary data with the permission of specific parties, including suppliers, manufacturers, service providers, and customers. Information written to the blockchain cannot be modified, preventing false data entries and improving demand forecasting with real-time information. Workflow tracking can be ensured by monitoring the data flow. Parties with restricted access to smart contracts will not be able to view the entire contract, regardless of access to the blockchain [7]. Solutions are available for sharing data under the control of trusted third parties using permissioned blockchains.

Blockchain technology can be utilized to reduce costs in healthcare due to Medicare and Medicaid reimbursement policies. If providers offer excessive capital investment, they may experience inadequate compensation and excessive costs. In such cases, blockchain technology can assist in establishing medical treatment historical information transfer and aggregation within capital constraints [8]. Furthermore, to prevent redundancy, quick and automatic search technology can be implemented on the blockchain layer to directly confirm whether patients have migrated from other medical institutions. Ethically, patients will have no control over their off-chain historical information, and illegal trading of patient identities and medical records will occur in the black market of healthcare big data for huge profits. So, by establishing a Azure chain-based blockchain technology architecture while deploying smart contracts to regulate on-chain activities automatically, the financial input avoidance of medical treatment would be realized.

3.1 Supply Chain Management

Quality and product traceability issues have become increasingly prominent in the food supply chain, necessitating the development of an effective and transparent food supply chain [9]. In 2020, the FDA partnered with the U.S. Department of Agriculture (USDA) to develop and implement the New Era of Smarter Food Safety initiative. This effort emphasized the need for novel technologies, especially those based on the Fourth Industrial Revolution (4IR), to enhance the food safety system and minimize foodborne illnesses. Specifically, a research team explored the implementation of blockchain technology, IoTT, artificial intelligence (AI), and big data in food traceability systems. An integrated, secure, and transparent blockchain-based automotive food supply chain framework for food tracking and traceability was developed. Smart contracts were designed to integrate AI with blockchain in the pseudonym blockchain network, providing an immutable record of all transactions. An innovative two-layer consensus mechanism was proposed to handle big data analysis and safeguard privacy [5].

Another illustrative case involves Starbucks, a multinational chain of coffeehouses and roastery reserves headquartered in Seattle, Washington, USA. In 2020, Starbucks collaborated with Microsoft to create a blockchain-based management system for tracing the food supply chain. This system provides consumers with transparent and complete information on the consumption of food ingredients in Starbucks products, allowing them to understand the entire journey of food from the farm to the store. The program was being tested in farms in Costa Rica, Colombia, and Mexico, where Starbucks sources coffee beans.

3.2 Healthcare

Blockchain technology has emerged as an effective solution for enhancing data integrity and transparency when it comes to sharing data between different parties. Each industry needs to adopt the right technologies for data management keeping in mind the internal and external factors, and the healthcare sector is no exception [10]. However, managing healthcare data that is to be shared with different parties while keeping its integrity is a major concern. Currently, healthcare providers and vendors maintain multiple copies of shared data. In this situation, if one copy is manipulated outside the authorized parties, there would be no way for the other parties to know about it. Additionally, the industry needs a technological medium for multiple parties to transact with trust. Such a transaction can be facilitated by building blocks that include entities like a standard data format, public keys for encrypting, an index for tracing transactions, third-party transacting entities (auditors), and a reliable information storage and transaction medium. Blockchain, the core technology behind bitcoin addresses this need. Some basic features of this technology are the decoupled ownership of data, existence of a plan to verify health conditions and treatment process enforced by smart contracts, and common standards for data sharing.

There are various challenges faced by the healthcare industry regarding fraud data sharing and its solution through smart contracts, as there is no trust between the parties sharing healthcare data [11]. Although multiple healthcare industries such as Humana and UnitedHealthcare are working on pilot programs with the Massachusetts Institute of Technology's Media Lab and others to maintain and share curated information from healthcare providers, it would still require national standard data formats. A research analysis has been conducted to examine how blockchain technology helps in managing and sharing healthcare data with its integrity and transparency.

3.3 Finance and Banking

The finance and banking sector is one of the first industries to explore the blockchain. From the payment system of Bitcoin to the exploration of large banks, securities firms, and insurance companies for applying blockchain technology to the development of DCEP digital currency, it can be said that blockchain is supporting the distributed and decentralized development of the finance and banking sector. The emergence of Bitcoin credit currency has enabled the standardization of distributed ledgers, and its key technology, the blockchain, has provided a basis for realising the division of trust and the new model of point-to-point transactions. Eventually, finance and banking based on distributed ledger technology (DLT) are the inevitable result of the development of current problems. As an open and shared network, P2P finance has the characteristics of low cost, openness, and inclusiveness. Afterwards, the basic models and experimental platforms of P2P credit currency, smart contracts, and micro-finance based on blockchain technology are further investigated [12]. The use of blockchain technology in finance and banking includes the application on finance and banking unified account systems based on cryptographic hash function and Merkle tree structures (comprehensive monitoring accounting system design scheme), as sheen Figure 4 finance and banking payment clearing system model of trust calculation and routing selection in real-time settlement on blockchain, analysis of security and application of blockchain core technology in financial markets, challenges and solutions of applying blockchain in finance and banking, and so forth.

From the implementation on public blockchain technology and smart contract technology in finance and banking transaction services (mainstream blockchain projects applied publicly in finance and banking), it can be seen that finance and banking focused on four aspects of business: cross-border remittance, asset tokenization, anti-fraud of securities transactions, and credit investigation. The application of blockchain technology strengthens transaction integrity and transparency, builds shared infrastructure for collaboration among financial institutions, prevents transaction fraud by means of tracking and auto-reporting legitimate transactions, and realise the real-time processing and settlement and reducing transaction costs of finance and banking transactions through P2P.

Figure 4. Blockchain technology for data integrity and security

4. Benefits and Challenges of Implementing Blockchain

The implementation of blockchain technology in various domains has been widely perceived positively and is encouraged by authorities and enterprises across the globe. Blockchain technology is no longer an emerging technology; it has matured into an innovative and well-integrated technology, giving rise to new business models focusing on decentralized services. It carries numerous advantages over traditional databases for certain use cases. However, it is often overgeneralized, and some use cases do not fit it well. Moreover, any new technology comes with a new set of challenges and risks. This section attempts to illustrate the benefits and challenges of implementing blockchain technology.

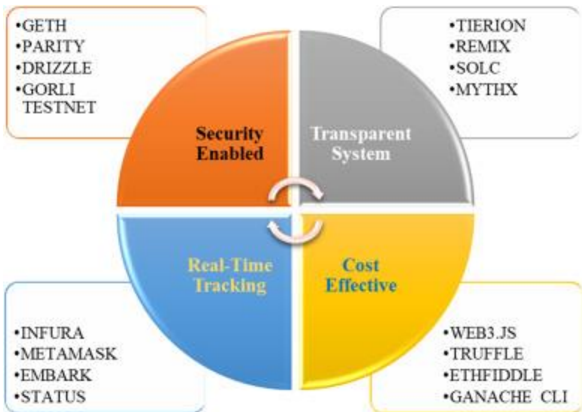

Figure 5. Blockchain technology applications for bank and financial domain

Nonetheless, blockchain technology does not stand out and outperform classical systems for every use case. It is, by nature, a distributed system, and there are several trade-offs that accompany this choice. Challenges include design and implementation hurdles. Blockchain technology is poorly understood, especially in larger enterprises, and there tends to be high uncertainty regarding the end product. Therefore, in these enterprises, blockchain projects suffer from high drop-out rates due to over-ambitious specifications, lack of use-case-focused design, or lack of technological feasibility [5].

4.1 Benefits of Blockchain Technology

Blockchain technology has emerged as a robust solution for enhancing data integrity and transparency across industries. With the proliferation of digital transactions, the need to ensure tamper-proof data and information has become paramount to foster user trust. Blockchain, often referred to as a distributed ledger, stores records across a network of nodes. Each record or transaction is represented as a block and is cryptographically linked to its preceding block, creating a chronological chain of records known as the blockchain. The records, once submitted and verified, are immutable, immutable, with any modifications or alterations requiring the consensus of a majority of the nodes. Additionally, each record is associated with a unique hash value, rendering any alterations to the record detectable. Being distributed and decentralized in nature, there is no single authority responsible for the records.

One of the key innovations of blockchain technology is smart contracts, which provide a tamper-proof mechanism for executing transactions. Smart contracts are computer codes that are deployed and run on the blockchain network. The advantages offered by blockchain technology have attracted the interest of researchers, governmental bodies, and organizations, leading to the development of several blockchain networks or platforms such as Bitcoin, Ethereum, Hyperledger Fabric, and others. Blockchain technology has numerous use cases across various sectors, including finance, banking, logistics, education, pharma, defense, retail, automobile, and healthcare. Practical examples and case studies will highlight the benefits offered by blockchain technology, and how it has improved the integrity and transparency of data and information across several industries.

4.2 Challenges and Limitations

Even though some industries are utilizing blockchain technologies, others remain cautious due to the numerous challenges and limitations such implementations may create. Such technologies can add costs associated with both automated monitoring and blockchain storage. There is concern about the uncertainty of new/additional costs associated with the technologies and a firm’s ability to compete with other firms that may not elect to adopt such technologies. Many stakeholders lack an understanding of blockchain technologies, particularly outside the development and operation domains. For some supply chain inspection stakeholders, such lack of understanding creates additional concern regarding blockchain implementation and storage [13]. Additionally, as the work of blockchain developers progresses, there is concern that systems will work improperly or inconsistently with contractual obligations. Outcomes could lead to undesired consequences, including increased costs and a lack of compliance with food safety standards.

Designing a blockchain-based solution to meet firm needs is complicated by practical limitations, including tons of data needing to be processed in near real time. Some supply chain inspection stakeholders may be resistant to sharing certain data regarding their processes with other firms (such risks add concern regarding proprietary data competing firms may use). Cryptographic mechanisms could allow stakeholders to remain competitive. However, such systems might not be fully trusted by some stakeholders. Smart contracts could be employed to automatically execute conditions under which stakeholders release certain data believed to be competitive (e.g., prices, number sold) [14]. However, such contracts must be written accurately, or an error could have severe consequences (e.g., automating the dissemination of too much data).

5. Case Studies

This section discusses two case studies of organizations that have adopted blockchain technology. The first case study focuses on Walmart's implementation of blockchain for food traceability. The second case study examines the collaboration between Maersk and IBM to leverage blockchain through the TradeLens platform.

Walmart is a well-known global retail corporation operating a chain of hypermarkets, discount department stores, and grocery stores. It has leveraged blockchain technology to improve the traceability and transparency of its food supply chain. By using IBM’s Food Trust blockchain platform, Walmart can track the origin of its food products in seconds, reducing the tracking time from six days to just two seconds. This case study illustrates how a well-established organization has adopted a relatively new and innovative technology to address food safety issues, enhance consumer confidence, and meet regulatory requirements [15].

Based on interviews with three experts, this case study discusses how the TradeLens platform is used to track container shipments across terminals around the globe. The paper highlights port congestion issues in recent years, fueled by the increasing globalization of trade and the need for more efficient logistics processes. These issues have economic and political implications, and several stakeholders in the shipping ecosystem are exploring ways to reduce logistics costs and improve efficiencies [16].

5.1 Walmart's Use of Blockchain in Food Traceability

Walmart is the largest food retailer in the United States. It provides a wide variety of food products in a global supply chain systems. However, as a food retailer, food safety problems are always a big issue [15]. In the last few decades, food safety issues have occurred frequently, including meat contamination, plastic residues in milk, and even food poisoning events caused by E. coli and Salmonella. These problems can cause huge economic losses in food supply chain systems and also threat to consumers' health. In order to ensure the food safety, food traceability systems are usually applied to collect, store, and analyze all food related information. The capability of back tracing the farm of products can enhance the efficiency of finding food contamination sources, minimize adverse effects, and make better decision support on recalling hazardous food. In United States food traceability systems, product traceback usually involves investigations of the History, Use, and Tracking of a product. The length of traceback path is critical. Longer traceback paths may increase investigation complexity. Traditional food traceability system documents the movement of products on paper or send-related information through e-mails. Each participant in the supply chain holds a separate database and information cannot be shared among each other. Thus, product movement information is not integrated and may be hard to backtrack. On the contrary, blockchain based traceability system can enable participants in the food supply chain systems to share relevant information, enhance efficiency and give better decision support of searching for contamination source[16].

In 2016, Walmart and IBM conducted a pilot study of blockchain based food traceability system together in their supply chain systems. This cooperation was initiated by concern of food poisoning caused by products distributed by multiple stores and large areas. The traceback time was nearly seven days to collect all of the information of mango movements from the farm to the store. Consultation to obtain data facts was also needed. Compare with traditional systems, the time could be greatly reduced to 2.2 seconds in blockchain based traceability systems. The difference in time performance is because each participant along the supply chains is provided with a copy of the whole data and transaction history. The incoming transaction of mangoes is recorded by the store's blockchain, and then the product information is included and passed along to the company's distribution center, which also records the mangoes' arrival and independently verifies the shipment [17].

5.2 Maersk and IBM's TradeLens Platform

The TradeLens platform is then analyzed from the perspective of Maersk, with attention to the external and internal challenges of supply chains. The latter also includes an assessment of existing security measures and how a wider adoption of blockchain affects them. A summary of the challenges and trade-offs accompanying the platform's construction and management, which still must be overcome to fully exploit the benefits of blockchain technology, is also provided. Overall, the goal is to foster a better understanding of this approach to blockchain in a case study with a holistic perspective [18].

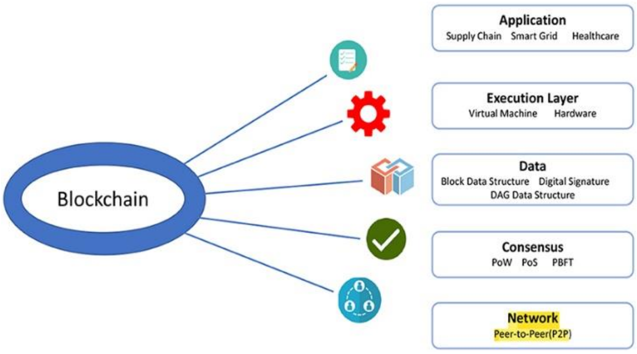

Figure 6. The role of blockchain technology in ensuring data

6. Regulatory and Legal Considerations

The implementation of blockchain technology, despite its growing interest, brings along regulatory and legal considerations. The emergence of smart contracts raises doubts on their enforceability and incapacity to deal with problems that depend on the interpretation of linguistic expressions. Dealing with the capacity of self-executing agreements to determine conflicting interests of the contracting parties and the absence of guarantees of fairness and equality must concern national security issues. Moreover, the irreversible nature of transactions creates a debate regarding consumer protection and the responsibility of the involved parties.

A liability theory for blockchain-based contracts arises from the disciplinary mechanism embedded in smart contract technology. Analyzing dysfunctions pre-determined by contractual schemas, a legal theory of digital obligation damages defines liable parties and even the legal consequences. Apart from the "intelligent" quality of such contracts, the blockchain technology underlying these smart agreements introduces an objective liability regime, which is completely external to the contract parties. This results in sanctions that entire networks can impose to ensure normal behavior [19].

7. Future Trends and Opportunities

Emerging trends in blockchain technology include expansion beyond cryptocurrency, increased focus on interoperability, and more energy-efficient consensus algorithms. Future applications encompass supply chain management, healthcare data management, secure digital identities, and peer-to-peer energy trading. Potential advancements include better scalability solutions, improved security protocols, more user-friendly development tools, and blockchain-based IoT applications.

The expanding awareness of the limitations of centralized systems, particularly following high-profile hacks and data leaks, is facilitating the adoption of blockchain technology in various sectors 20. From banking to supply chain management and the trade sphere, blockchain is being increasingly seen as a means to ensure data integrity and transparency.

8. Conclusion

This essay deliberates on blockchain technology, elucidating its significance and purposes in the current business environment. The investigation demonstrates the components involved in blockchain technology and the various properties and differences of public, private, and consortium blockchains. Furthermore, it explores the impact of blockchain on the banking and financial sectors, along with the progressive effects envisioned for such sectors with the inception of the technology. The investigation also focuses on the impacts of blockchain technology upon industries like healthcare, supply chain management, and IoT. Subsequently, it deliberates on the challenges and risks concerning the implementation of blockchain technology.

Emerging in recent years, blockchain technology is getting closer to its breakout moment. Actually, 2018 witnessed an unprecedented rise in the development, working, and maturity of blockchain adoption across diverse sectors. Blockchain technology is now seen by many key players in industry and academia as a transformative technology that would enable new services and act as enabler of new business models. Data integrity, the strong point of Blockchain technique, is the reason why its use extends also to other domains and applications. Therefore, Blockchain is advocated by many as the next big thing of the Internet and has the full potential of revolutionizing data privacy, trust, security, and the relationship with individual information on the Internet.

8.1 Summary of Key Findings

A thorough analysis of blockchain technology has been undertaken, examining its fundamental principles, key characteristics, and diverse applications across various sectors, including finance, supply chain, healthcare, IoT, energy, identity and access management, digital asset tokenization, media and entertainment, voting, and government. Importantly, the notion of blockchain has undergone significant development, enabling the integration and utilization of blockchain technology in conjunction with other innovative technologies, such as AI, IoT, edge computing, 5G, and big data. Smart contracts, decentralized finance, and the metaverse constitute some of the pivotal abstractions associated with the new blockchain paradigm. In the context of Web3, blockchain-based solutions will copiously proliferate, empowering individuals to compete with big tech companies and compelling pre-existing web 2.0 industry incumbents to adapt to the blockchain age. This transitional evolution from an Internet of information to an Internet of value, decentralization, and dissemination of trust will have profound ramifications on economies, governance models, and societal structures [14].

Data integrity and transparency have emerged as paramount concerns for organizations and industries across the globe. Consequently, innovative technologies, such as blockchain, are being increasingly leveraged by various businesses to realize the industrial internet [20]. Emerging blockchain-powered data integrity and transparency technologies can monitor and regulate industrial data utilization potentially, thus fostering greater trust among various parties and enhancing situational awareness of data utilization in mechanical production and manufacturing.

8.2 Implications for Industries

Enhancing data integrity and transparency is a critical requirement for industries. Blockchain technology allows users to share and maintain a common digital ledger (or database) of transactions/information. The same ledger is replicated in real-time across all users' devices, reducing the risk of data manipulation and ensuring all users have accurate and up-to-date data. With this technology, each transaction is cryptographically protected making it tamper-proof and preventing unauthorized access. Thus, blockchain implementations in industries lead to enhanced data integrity and transparency.

Since the advent of cryptocurrency "Bitcoin" in 2009, blockchain technology has been applied in different sectors to solve critical requirements. Blockchain was drastically adopted for Financial and Banking sectors in the initial stage as they have high requirements for data integrity, security, and transparency. Besides Financial and Banking; Healthcare, Supply Chain, Internet of Things, Real State, Education, Music, Entertainment, Election, etc. are popular sectors in which blockchain technology could provide potential solutions [8].

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