Blockchain Technology in Various Fields: Applications, Challenges, And Future

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Abstract. Blockchain technology has revolutionized many industries and has great potential outside of finance. This paper explores blockchain's applications and challenges in agriculture, electricity, transportation, healthcare, and finance. Blockchain technology can track agricultural product origin, quality, and safety to improve supply chain transparency in agriculture. Blockchain can also reduce intermediaries, improve payment systems, and expand financing. Blockchain can enable decentralized electricity management, peer-to-peer energy transactions, and lower transaction costs. It could boost renewable energy integration, grid efficiency, and energy access for underserved communities. Blockchain technology can improve transportation supply chain visibility and reduce fraud by providing a shared, tamper-proof ledger to track goods and prevent unauthorized access. Blockchain can secure, interoperable, and improve patient privacy in healthcare. It could let patients share their health data with providers and researchers while protecting their privacy. Blockchain implementation is also tricky. Scalability, interoperability, compliance, and data privacy Blockchain solutions must handle large amounts of data, integrate with existing systems, comply with laws and regulations, and protect sensitive data. Further research and development are necessary to explore blockchain technology's possibilities in these fields fully.

Keywords: Blockchain, Applications, Transparency, Security, Interoperability.

1. Introduction

A blockchain is a distributed database system consisting of a chain of data blocks or packets generated using cryptographic methods, with each block of data information automatically timestamped so that a data encryption value, known as a hash value, can be calculated. Each block contains a hash of the block that is linked to the current area from the initial block, thereby creating a blockchain. Essentially, it is a node trust mechanism established by the universal adoption of nodes created using encryption algorithms based on Internet big data [1, 2].

Theoretically, when the number of nodes in the blockchain reaches a sufficient threshold, this trust creation mechanism with broad public participation will be able to establish trust, reach contracts, establish transactions, and provide automatic public disclosure and common supervision without the authorization of the "center" [3, 4].

With the increasing demand for decentralized authentication technology and security and the strong rise of digital currencies represented by Bitcoin, the emerging blockchain technology has become a new development direction and is gradually being applied in finance, transportation, network security, energy, and other related fields, as shown in Figure 1.

In agriculture, blockchain technology is widely used in production traceability, quality and safety management of agricultural products, logistics and distribution, financial services, and other aspects.

In the energy sector, blockchain technology creates a more efficient and secure global energy supply chain management system. Using blockchain technology in the energy industry may increase distribution efficiency, cut costs, and allow real-time energy usage monitoring and control.

In transportation, blockchain technology transforms logistics, supply chain management, and smart travel. It may enhance transportation safety, logistical efficiency, monitoring of real-time traffic data, and tailored travel solutions.

In the medical business, blockchain technology is utilized to tackle data security challenges, information exchange on patient consultations, and medical insurance claims. The adoption of blockchain technology in the medical business may also assist medical research and medication

development by facilitating the safe exchange of medical data and enhancing the protection of patient privacy via authentication and authorization methods.

Ultimately, blockchain technology can transform how humans conduct transactions, handle data, and connect. As blockchain technology continues to evolve and advance, it is anticipated that an increasing number of sectors will embrace it, fueling its development and innovation.

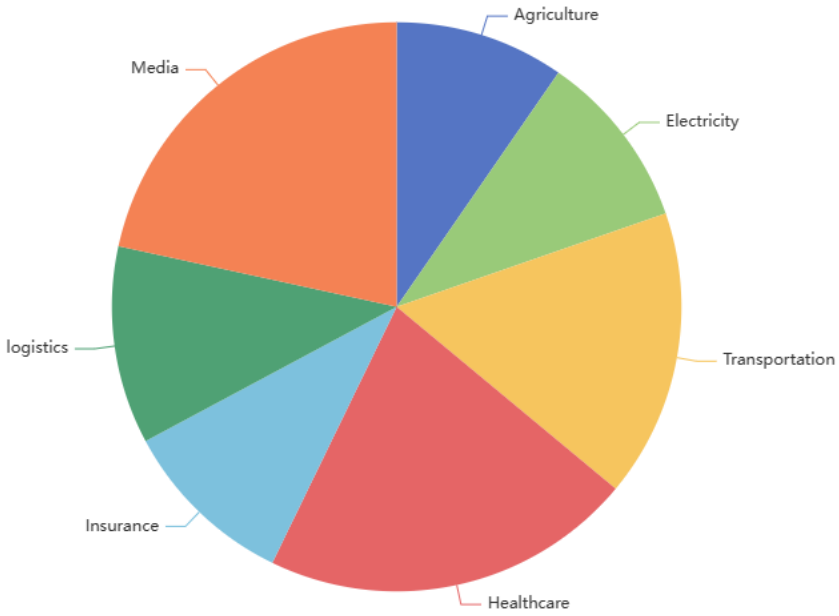

Fig. 1 Blockchain technology in various sectors

2. Preliminaries

The blockchain is a peer-to-peer network that uses cryptography and consensus mechanisms to generate and store massive transaction data chains [5].

Each block includes the encrypted hash of the previous block, a timestamp, and transaction data (typically represented by the hash value of the Merkle tree algorithm) [6]. This design improves the block. The content requires assistance to improve its quality. If a user controls more than 51 percent of the computing power of the blockchain's nodes, he or she can manipulate the blockchain's data. If the initial content is erroneous, blockchain technology only makes it more difficult to correct the error.

The most prominent application of blockchain technology at present is a digital currency like Bitcoin. Because the essence of the payment is "adding the reduced amount from account A to account B." People are able to determine the current account balance if they have access to a public ledger that lists all account transactions to date. Specifically, the public blockchain (public chain) serves this function as the public ledger. A bitcoin address corresponds to an account in the Bitcoin system, and the quantity of bitcoins corresponds to an amount.

2.1. Structure and design

Logically, a blockchain can be seen as consisting of several layers [7]. 1) Application layer. The blockchain's topmost layer provides end-user functionality and interface. Smart contracts, decentralized applications, and other blockchain-interacting software are included. The application layer lets users interact with the blockchain on top of the data layer. 2) Data layer. The data layer stores blockchain data. It includes transaction, user, and other relevant data blocks. Immutable and tamper-proof data layers make it hard to change blockchain data. The consensus layer validates data using the data layer on top. 3) Consensus layer. The consensus layer verifies blockchain data. The consensus mechanism validates and verifies transactions. The consensus layer connects the network layer to other blockchain nodes. 4) Network layer. Blockchain nodes communicate via the network

layer. The peer-to-peer network transmits data between nodes. The network layer interacts with the blockchain on top of the environment layer. 5) Enviroment layer. The environment layer contains the blockchain's hardware and software. It includes blockchain nodes, the operating system, and other software. The environment layer ensures blockchain security, reliability, and scalability.

2.2. Algorithms

Hash function. A hash function is a mathematical function that accepts inputs of any size and returns hash values of a fixed size. The hash function safeguards the data in a blockchain, as shown in Figure 2.

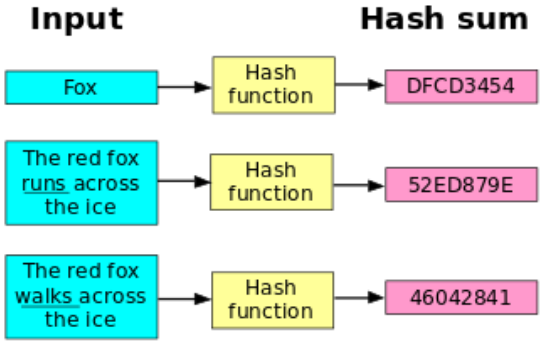

Fig. 2 Hash function

Proof of Work (PoW). Proof-of-Work (PoW) is utilized by blockchain technology to validate transactions and generate new blocks. To win cryptocurrency, PoW miners compete to solve complex mathematical puzzles. Bitcoin and Ethereum both utilize Proof of Work.

Merkle tree. Blockchain technology uses Merkle trees to verify large data sets efficiently. Recursively hashing data pairs yields a Merkle tree's root hash. Root hash verifies tree integrity.

Smart contracts. Buyer-seller contracts written in code are self-executing. Blockchain smart contracts automate contract execution and enable trustless transactions.

Private key/public key. Blockchain technology uses private keys to access cryptocurrency holdings and sign transactions. Public keys receive cryptocurrency and verify transactions. Public and private keys protect cryptocurrency holdings and transactions.

Immutable Ledger. A database with immutable data cannot be changed. The blockchain ledger is immutable, so transactions cannot be changed or deleted. This protects blockchain data.

Consensus algorithm. Blockchain consensus algorithms ensure that all network nodes agree on the blockchain's state. Blockchain technology uses PoW, PoS, and DPoS consensus algorithms.

3. Application in various fields

3.1. Agriculture

In recent years, the application of blockchain technology in the agricultural sector has received increasing attention. Statistics show more than 50 application cases for adopting blockchain technology in the global agricultural field [8]. In agriculture, blockchain technology is widely used in production traceability, quality and safety management of agricultural products, logistics and distribution, financial services, and other aspects.

First, blockchain technology is important in both agricultural production traceability and quality and safety management. By recording and tracking information on the production, flow, and sale of items, blockchain technology can significantly improve the safety and quality of food products and allow consumers to fully understand the production process and environment of the products, thus strengthening trust in the food itself. For example, China's "blockchain + traceability" technology has successfully traced agricultural products such as rice, vegetables, and fruits. In addition, Japan's "Food for Peace of Mind" project uses blockchain technology to track every agricultural product from

all angles, thus providing the necessary food safety assurance during a natural disaster [9]. In the US, the Farm-to-Fork project stores information about each cow on the blockchain, allowing consumers to identify the source and processing of beef, thus increasing consumer confidence [10].

Blockchain technology also has great potential for agricultural logistics and distribution. The IBM Food Trust platform uses blockchain technology to manage the global food supply chain, improving distribution efficiency and reducing costs. Similarly, China's "vegetable basket" blockchain platform delivers agricultural products to enhance data security for the entire e-commerce platform.

It is worth pointing out that blockchain technology can also provide financial services for agriculture. Rural finance has always been difficult, but blockchain technology can make agricultural finance more popular and transparent. Through blockchain technology, objectives such as precise poverty alleviation and the construction of rural credit systems can be achieved. For example, China's "wheat loan" project uses blockchain technology to provide credit loans to wheat farmers.

3.2. Electricity

The global energy market is evolving, requiring more efficient and secure trading solutions. Blockchain technology has grown in popularity in the electrical business. Blockchain technology can enable secure and transparent transactions without intermediaries. Decentralized and tamper-proof transaction records ensure electrical transaction security and transparency.

Smart contract-based green energy transaction models have been developed using blockchain technology in the electricity industry. These models can automate green energy transactions, lower expenses, and improve the reliability and traceability of electricity transactions. Smart contracts automatically execute under specified conditions. They automate electricity trading, including pricing and settlement, and provide real-time energy use monitoring and management.

Smart contracts and blockchain-based electricity market procedures have been proposed. Virtual electricity exchanges provide efficient and automated electricity trading between suppliers and consumers. These exchanges enable peer-to-peer trade and renewable energy grid integration.

In the power sector, blockchain technology is being combined with other technologies like AI and the Internet of Things (IoT). AI and IoT can automate power transfers and equipment monitoring in a blockchain-based smart energy system. This device can continuously monitor electricity quality and share data. The electrical distribution system can now leverage blockchain technology for autonomous decision-making and self-coordination. This can boost electrical distribution system efficiency, reliability, and security.

Many companies are exploring more practical applications. The European energy exchange EPEX SPOT and Blockchains LLC have launched a blockchain-based electricity trading platform that may combine distributed energy and electricity trading and enable real-time monitoring and tracking. Blockchain technology provides a safe, transparent trading environment and real-time energy market and price data.

In conclusion, blockchain technology in electricity could transform energy production, distribution, and consumption. Blockchain technology automates energy trade, secures transaction records, and allows real-time energy consumption monitoring and management. Blockchain technology may be used more in the electrical sector and beyond as the energy market evolves.

3.3. Transportation

Logistics, supply chain management, transportation, and smart travel use blockchain technology to transform the transportation industry. Blockchain technology could improve logistics safety and efficiency. Blockchain technology can track and monitor logistics data in real-time, preventing product loss and destruction. This helps deliver goods on time and in good condition, which is crucial for customer satisfaction.

Blockchain technology can also speed up supply chain data exchange, reducing information asymmetry and manipulation. Blockchain-enabled supply chain finance platforms can better track

capital flow, ensuring suppliers are paid on time. This improves supply chain efficiency and reduces payment delays and disputes [11].

Blockchain technology can also enable real-time traffic data monitoring and control, preventing accidents. Traffic data from cameras, sensors, and GPS devices can be stored on a blockchain-based platform. This data can be analyzed to identify traffic hazards like accidents and road closures and alert drivers. This can reduce accidents and improve transportation safety.

The blockchain-powered smart travel platform may offer customized travel solutions and improve travel comfort. A blockchain-based platform can store travelers' preferred airlines, hotels, and activities. This information can give travelers personalized travel itineraries, hotel recommendations, and activity suggestions. This can improve travelers' satisfaction and experience.

In conclusion, blockchain technology is proliferating in the transportation industry and has the potential to transform it. Blockchain technology can improve transportation safety, logistics efficiency, real-time traffic data monitoring, and customized travel solutions. As the transportation industry evolves, more innovative blockchain technology applications will improve efficiency, safety, and customer satisfaction.

3.4. Healthcare

As the maturity and development of blockchain technology continues, an increasing number of startups are investing in it. As a major industry application landscape, the medical field has witnessed a year-over-year increase in the proportion of strategic investment layouts by major corporations, government departments, and investment institutions, which have begun to rapidly lay out the application of blockchain technology in the medical industry.

In the medical field, Blockchain's decentralized distributed ledger and smart contracts can, to a certain extent, solve the problems of data security, patient consultation information sharing, and medical insurance claims. Currently, blockchain's distributed ledger and data security are the most prevalent applications in the medical industry. Every piece of medical record data stored on the blockchain carries a unique timestamp and encryption key. By storing the medical record data of patients on distributed servers, it is possible to ensure the data's integrity and non-comparability, thereby enhancing the credibility of medical data.

The medical field needs to be more balanced with the unequal allocation of medical resources. The use of blockchain technology allows for the sharing of medical record information. Remote consultation with the help of the Internet provides doctors with convenient access and management and contributes to further improvement of treatment in areas with underdeveloped health conditions.

In addition, blockchain technology can also facilitate medical research and drug development. Medical research and drug development require a large amount of data. However, due to medical data's sensitive and private nature, it is often difficult to access and share medical data. Blockchain technology, however, can enable the secure sharing of medical data by establishing a decentralized data-sharing platform and better-protecting patients' privacy through authentication and authorization mechanisms. However, the full implementation of blockchain technology in the healthcare sector faces numerous obstacles, including the technology's complexity and performance issues, the standardization of healthcare data, and legal and ethical restrictions.

4. Discussion

Blockchain technology has several drawbacks despite its potential benefits. Scalability is difficult. Blockchain technology cannot handle the transaction volume needed for widespread adoption in many industries. Blockchain networks have limited processing power and storage. Regulatory uncertainty is another issue. Businesses need more regulations to adopt blockchain technology. Regulatory compliance is crucial in finance and healthcare. Blockchain adoption raises security concerns. Blockchain networks have been hacked, and digital assets are stolen despite their security. To prevent such incidents, strong security is needed.

Researchers can develop new blockchain consensus algorithms that can handle more transactions to address scalability. Proof of Stake is more energy-efficient and scalable than Proof of Work.

Researchers can collaborate with policymakers and industry stakeholders to establish blockchain technology adoption guidelines to reduce regulatory uncertainty. Businesses considering blockchain technology may benefit from a more stable regulatory environment.

Researchers can create and improve blockchain security protocols to address security concerns. Multi-factor authentication, encryption, and other security measures can prevent hacking and theft.

In conclusion, blockchain applications have huge potential in many fields, making academic research essential. Scalability, regulatory uncertainty, and security are also issues. Researchers can solve these problems to accelerate the adoption of blockchain technology in various industries. If used properly, blockchain technology can transform many industries and benefit businesses and consumers.

5. Conclusion

Outside of banking, blockchain technology has the potential to transform several sectors. Its decentralized and immutable features make it a potent instrument for assuring transparency, security, and efficiency in several industries. By tracing food supply chains and verifying product authenticity, blockchain may aid in fostering trust between farmers and customers in agriculture. It may promote peer-to-peer energy trading and enable the integration of renewable energy sources in the electrical industry. It may allow safe and efficient data exchange among players in the transportation industry and enhance the management of logistics and supply chains. It may strengthen patient data privacy, improve clinical trials, and facilitate the secure exchange of medical information in the medical industry. For widespread use, blockchain technology must overcome many difficulties. As blockchain networks grow, scalability becomes a problem. Interoperability is another issue because blockchain systems and protocols are incompatible. Blockchain-based applications must also be regulated and legitimized. These difficulties require collaboration from governments, corporations, and communities. Blockchain research should improve scalability, interoperability, and security. Education and awareness initiatives are needed to show people how blockchain can solve real-world problems. In conclusion, blockchain technology has the potential to disrupt many industries and is growing rapidly outside of banking. Its decentralized, transparent, and secure data and transaction management can boost efficiency, lower costs, and build confidence. Scalability, interoperability, and regulatory frameworks are also issues. Blockchain can improve equity, sustainability, and security with stakeholder collaboration.

References

[1] Sangeetha, K. N., Singh, S., & Usha, B. A. (2022). Development of Novel Blockchain Technology for Certificate Management System using Cognitive Image Steganography Techniques. JOURNAL OF ALGEBRAIC STATISTICS, 13(2), 3032-3041.

[2] Andolfatto, D., & Martin, F. M. (2022). The Blockchain Revolution: Decoding Digital Currencies. Federal Reserve Bank of St. Louis Review.

[3] Wang, Z., Li, M., Lu, J., & Cheng, X. (2022). Business Innovation based on artificial intelligence and Blockchain technology. Information Processing & Management, 59(1), 102759.

[4] Erol, I., Neuhofer, I. O., Dogru, T., Oztel, A., Searcy, C., & Yorulmaz, A. C. (2022). Improving sustainability in the tourism industry through blockchain technology: Challenges and opportunities. Tourism Management, 93, 104628.

[5] Jothi, K. R., & Oswalt Manoj, S. (2022). A Comprehensive Survey on Blockchain and Cryptocurrency Technologies: Approaches, Challenges, and Opportunities. Blockchain, Artificial Intelligence, and the Internet of Things: Possibilities and Opportunities, 1-22.

[6] Hashim, F., Shuaib, K., & Zaki, N. (2022). Sharding for Scalable Blockchain Networks. SN Computer Science, 4(1), 2.

[7] He, N., Wang, H., Wu, L., Luo, X., Guo, Y., & Chen, X. (2022). A Survey on EOSIO Systems Security: Vulnerability, Attack, and Mitigation. arXiv preprint arXiv:2207.09227.

[8] Chaganti, R., Varadarajan, V., Gorantla, V. S., Gadekallu, T. R., & Ravi, V. (2022). Blockchain-based cloud-enabled security monitoring using Internet of Things in smart agriculture. Future Internet, 14(9), 250.

[9] Kör, B., Krawczyk, A., & Wakkee, I. (2022). Addressing food loss and waste prevention. British Food Journal, 124(8), 2434-2460.

[10] Lu, Y., Li, P., & Xu, H. (2022). A Food anti-counterfeiting traceability system based on Blockchain and Internet of Things. Procedia Computer Science, 199, 629-636.

[11] Mekouar, L., Iraqi, Y., Damaj, I., & Naous, T. (2022). A survey on blockchain-based Recommender Systems: Integration architecture and taxonomy. Computer Communications, 187, 1-19.