

# *Discussion on the security and legal effect of electronic signature based on blockchain technology*

**Yanjun Zhan**

*Guangdong Deyang Law Firm, Guangdong, Zhuhai, 519000, China*

**Keywords:** Blockchain technology; Security and legal effect; Electronic signature

**Abstract:** As a key element of digital transaction, electronic signature improves transaction efficiency, but it also faces security risks such as information disclosure, identity fraud and uncertainty of legal effect. Blockchain technology provides a new way to solve these problems with its decentralized, tamper-proof and transparent characteristics. Firstly, this paper analyzes the application of blockchain technology in ensuring the non-tampering, integrity and traceability of electronic signatures, and points out its advantages in preventing signatures from being disguised or tampered with. Then, it discusses how blockchain technology can enhance the legal effect of electronic signature, including its influence on the basis of legal effect of electronic signature, its application in electronic contract signing and its promotion effect on legal effect. In addition, the paper also discusses the challenges faced by blockchain technology in the field of electronic signature, such as insufficient technical maturity, privacy protection issues and conflicts with the traditional legal system, and puts forward corresponding solutions, including continuous technological innovation and the establishment of a legal and compliance framework that adapts to the characteristics of blockchain. Through these discussions, this paper aims to provide theoretical support and practical guidance for the wide application and development of blockchain technology in the field of electronic signature.

## **1. Introduction**

As a key element in digital and electronic transactions, electronic signature is gradually becoming an important way to replace traditional handwritten signature. The appearance of electronic signature greatly improves the transaction efficiency, reduces the time and cost, strengthens the accountability mechanism, reduces the environmental burden, and provides strong support for the digital transformation of all walks of life. However, the wide application of electronic signature is accompanied by a series of security problems. Risks such as information leakage and identity fraud occur from time to time, which makes the authenticity and security of electronic signatures questioned [1]. At the same time, the uncertainty of the legal effect of electronic signature has also become a bottleneck restricting its further development. Although the relevant laws and regulations stipulate the legal effect of electronic signature, there are still many disputes and problems in actual operation.

As a new technical means, blockchain technology has shown great application potential in various fields with its characteristics of decentralization, non-tampering and transparency [2]. The

core principles of blockchain technology, such as distributed network, encryption algorithm and consensus mechanism, provide new ideas and methods for solving the security and legal effect of electronic signatures [3].

Through in-depth analysis of the overview of electronic signature, the basic principle of blockchain technology and its application in electronic signature, this paper reveals how blockchain technology can solve the problems of security and authenticity verification of electronic signature and how to enhance the legal effect of electronic signature.

## 2. Application of blockchain technology in electronic signature security

Blockchain technology uses advanced encryption algorithms to ensure the tamper resistance and integrity of electronic signatures. In the blockchain network, each data block contains certain information, and these information are closely linked together through encryption algorithms, forming an unbreakable chain [4]. When an electronic signature is created and added to the blockchain, it is encrypted and stored with other data blocks. This encryption method ensures that the electronic signature will not be maliciously tampered with or destroyed during transmission and storage, thus ensuring its integrity and authenticity. Figure 1 shows the principle of blockchain technology.

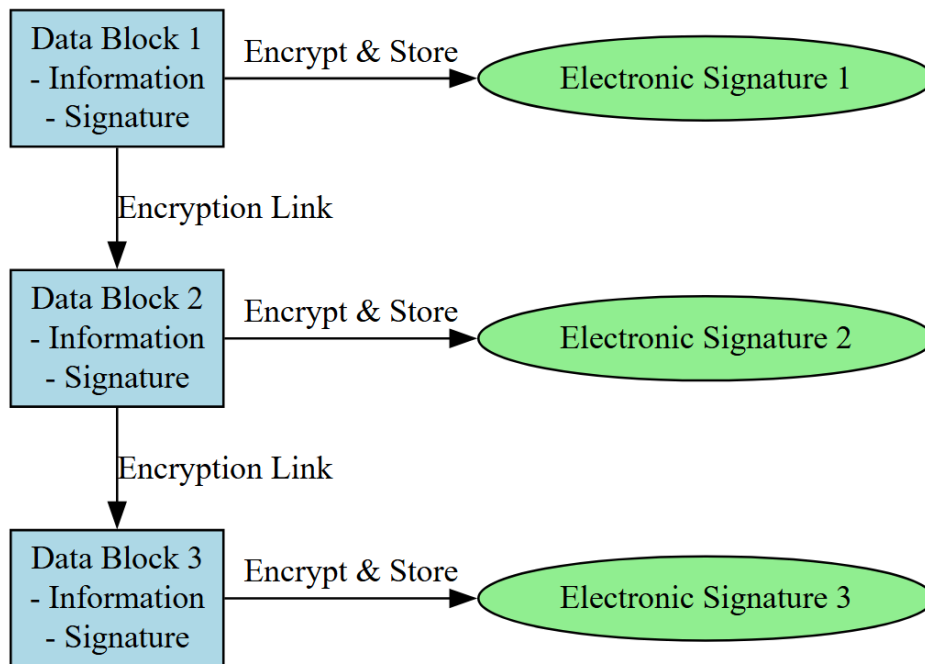


Figure 1 Blockchain technology principle

Through the distributed ledger technology of blockchain, the traceability of electronic signatures can be realized. In the blockchain network, each node keeps a complete copy of the account book, which means that the information of electronic signature is widely distributed on all nodes in the network [5]. When the authenticity of the electronic signature needs to be verified, the source, creation time and related transaction information of the signature can be confirmed by tracing the records on the blockchain. This traceability not only enhances the credibility of electronic signature, but also provides strong evidence support for solving potential disputes.

Blockchain technology has shown remarkable advantages in preventing signatures from being disguised or tampered with. Due to the decentralized nature of the blockchain network, any tampering or camouflage of electronic signatures will be quickly discovered and rejected by other

nodes in the network. The consensus mechanism of blockchain ensures that only verified and recognized transactions can be added to the chain, which further enhances the security and reliability of electronic signatures [6]. In addition, blockchain technology can also provide a higher level of security for electronic signatures by combining technical means such as identity authentication and digital certificates.

Blockchain technology provides an effective solution for the security and authenticity verification of electronic signatures through its unique encryption algorithm and distributed ledger technology [7]. It not only ensures the tamper-proof and integrity of the electronic signature, but also realizes the traceability of the electronic signature, and also shows remarkable advantages in preventing the signature from being disguised or tampered with.

### **3. Discussion on the legal effect of blockchain technology in electronic signature**

#### **3.1. Legal validity basis of electronic signature**

Blockchain technology has enhanced the security and reliability of electronic signature through its characteristics of non-tampering and traceability, provided new technical support for electronic signature, and affected its legal effect. According to the Electronic Signature Law of People's Republic of China (PRC), electronic signatures have obtained the same legal status as traditional signatures, and the technical and legal conditions needed to ensure their security and accuracy have been defined [8]. The law also regulates the qualifications and responsibilities of electronic certification service providers to enhance the credibility of electronic signatures. In addition, the Contract Law and other relevant laws and regulations supplement the validity of electronic contracts and signatures, while international treaties and bilateral agreements provide an international legal basis for the mutual recognition and implementation of electronic signatures.

Blockchain technology provides strong technical support for electronic signature and enhances the legal effect of electronic signature. However, with the development of technology, laws need to constantly adapt to new challenges. By perfecting laws and regulations, strengthening international cooperation and promoting standardization, we can further enhance the legal effect of electronic signatures and promote the healthy development of digital economy.

#### **3.2. Blockchain technology and legal effect of electronic signature**

The traditional electronic signature relies on the third-party certification authority to verify the authenticity of the signature, while the blockchain technology makes the verification of electronic signature no longer rely on a single trust authority through decentralization. Each participating node can verify the authenticity of the signature, thus greatly reducing the possibility of forging the signature [9]. Once the data on the blockchain is recorded, it cannot be modified or deleted. This non-tampering ensures the authenticity and integrity of the electronic signature, which makes the electronic signature have stronger legal effect. The transparency of blockchain technology enables all transaction records to be publicly queried, which enhances the public's trust in electronic signatures. This transparency helps to reduce disputes arising from information asymmetry. The smart contract on the blockchain can automatically execute the contract terms, which reduces the possibility of human intervention and improves the efficiency and accuracy of electronic signature.

#### **3.3. The application of blockchain technology in electronic contract signing**

Through the distributed ledger technology of blockchain, the user's identity information and public key can be safely stored, and the decentralized authentication of identity can be realized.

This helps prevent identity theft and impersonation. Using the hash algorithm of blockchain, the contract content can be transformed into a unique digital fingerprint to ensure the consistency and integrity of the contract content. Any tampering with the contents of the contract will be discovered immediately. Blockchain can record the signing process of the contract in detail, including the signing time, place, participants and other information, providing strong evidence support for the performance of the contract. The distributed account book feature of blockchain enables contract data to be backed up on multiple nodes, ensuring the durability and security of data. Even if a node fails, the contract data can still be recovered.

### 3.4. The influence of blockchain technology on the legal effect of electronic contracts

The decentralized trust mechanism, non-tampering and transparency provided by blockchain technology greatly improve the credibility and legal effect of electronic contracts. Therefore, electronic contracts are more likely to be recognized and supported by the court. Through the application of intelligent contract, the execution and performance of electronic contract become more automatic and efficient, which reduces the possibility of manual intervention and mistakes and reduces the risk of contract disputes. Blockchain technology has promoted the innovation and development of electronic contract legal system, and prompted the legal profession to re-examine and adjust the existing legal provisions to meet the requirements of the digital age.

## 4. Challenges and solutions of blockchain technology in the field of electronic signature

### 4.1. Challenges faced

As an emerging force in the field of electronic signature, blockchain technology has brought unprecedented security and efficiency improvement, but it also faces many challenges in practical application. Despite its rapid development, its technical maturity is still insufficient, and there are stability and performance problems, which pose challenges to electronic signatures with high security requirements; Although the transparency of blockchain enhances data traceability, it also raises privacy protection issues, especially when it comes to sensitive information such as personal identity and transaction details; Due to the decentralized nature of blockchain, it conflicts with the traditional legal system, and the differences of laws and regulations in various countries make the legal effect of electronic signatures and the compliance of cross-border transactions an urgent problem to be solved. The main challenges faced by blockchain technology in the field of electronic signature are shown in Table 1.

Table 1 Challenges faced by blockchain technology in the field of electronic signature

Challenge category	Description of specific challenges
Technical maturity	<ol style="list-style-type: none"> <li>1) Although blockchain technology has developed rapidly, it is still in a relatively initial stage, and there are problems such as technical instability and performance bottlenecks.</li> <li>2) The application of electronic signature has extremely high requirements for security and reliability, which puts forward higher standards for the maturity of blockchain technology.</li> </ol>
secret protection	<ol style="list-style-type: none"> <li>1) The openness and transparency of blockchain enhances the traceability of data, but it also increases the risk of privacy leakage.</li> <li>2) Electronic signature involves a lot of sensitive information, such as personal identity, transaction details and so on. How to effectively protect these privacy has become an urgent problem to be solved.</li> </ol>
Law and compliance	<ol style="list-style-type: none"> <li>1) 1) The decentralized nature of blockchain technology may conflict with the existing traditional legal system, which may lead to the legal validity of electronic signatures being questioned.</li> <li>2) The laws and regulations on blockchain and electronic signature are not uniform in various countries and regions, which may bring legal compliance risks to cross-border transactions.</li> </ol>

## 4.2. Solution

### 4.2.1. Continuous technological innovation

Increase investment in research and development of blockchain technology, promote continuous technological innovation, and improve the performance and stability of blockchain. This includes in-depth research and development of blockchain consensus algorithm, encryption technology, smart contract and other aspects to continuously improve the scalability, security and efficiency of blockchain. According to the specific requirements of electronic signature, the architecture and algorithm of blockchain are optimized to improve its application effect in the field of electronic signature. For example, we can study how to combine blockchain with existing electronic signature technology to achieve a safer, more efficient and more convenient electronic signature solution. Researchers and technical developers should introduce more advanced encryption technologies and anonymization methods to ensure the security and privacy protection of electronic signature data during transmission and storage. Advanced encryption algorithms such as zero-knowledge proof and homomorphic encryption, as well as anonymous methods such as ring signature and group signature are adopted to enhance the security and privacy protection of electronic signatures.

### 4.2.2. Establish and improve the legal and compliance framework that adapts to the characteristics of blockchain

Strengthen cooperation with international organizations, promote the formulation of unified legal standards for blockchain and electronic signatures, and enhance the international legal effect of electronic signatures. This will help promote mutual recognition and interoperability of electronic signatures worldwide and provide more convenient and efficient services for cross-border e-commerce and other fields. Governments of all countries should actively study and adapt to the characteristics of blockchain technology, revise and improve relevant laws and regulations, and provide legal protection for the application of blockchain technology in the field of electronic signature. For example, special laws or regulations on blockchain electronic signature can be formulated to clarify its legal status, scope of effectiveness and related responsibilities and obligations. Regulatory authorities of various countries should establish and improve the supervision mechanism of blockchain technology, strengthen the supervision of electronic signature service providers, ensure their compliance operations, and protect the legitimate rights and interests of users. This includes the regulatory requirements for the qualification review of providers, the definition of business scope, data security management, and penalties for violations.

Blockchain technology faces multiple challenges in the field of electronic signature, such as technical maturity, privacy protection, law and compliance. However, these challenges can be gradually overcome by continuous technological innovation, introduction of more advanced encryption technology and anonymization methods, and establishment and improvement of legal and compliance framework adapted to the characteristics of blockchain, so as to promote the wide application and development of blockchain technology in the field of electronic signature.

## 5. Conclusion

Blockchain technology effectively guarantees the tamper-proof and integrity of electronic signatures through its unique encryption algorithm and distributed account book technology. Each data block is encrypted and closely linked, forming an unbreakable chain to ensure the security of electronic signature during transmission and storage. At the same time, the decentralized nature of the blockchain enables any tampering or camouflage of electronic signatures to be quickly

discovered and rejected, further enhancing the authenticity and reliability of electronic signatures. Blockchain technology provides strong technical support for electronic signature and enhances its legal effect through its characteristics of non-tampering and traceability. In addition, the application of smart contracts makes the execution and performance of electronic contracts more automatic and efficient, reduces the possibility of human intervention and mistakes, and further reduces the risk of contract disputes. Although blockchain technology has performed well in improving the security and legal effect of electronic signatures, it also faces challenges such as privacy protection and legal compliance. Although the transparency of blockchain technology enhances the traceability of data, it may also lead to the risk of privacy leakage. Therefore, it is necessary to introduce more advanced encryption technology and anonymization methods to enhance the privacy protection ability of electronic signatures. At the same time, due to the conflict between the decentralized characteristics of blockchain and the traditional legal system, the laws and regulations on blockchain and electronic signature are not uniform in various countries and regions, which brings legal compliance risks to cross-border transactions.

## References

- [1] Huang K, Li X, Yuan S, Liu X Y, & Zhang X. (2024). *Public Key Cryptography in Blockchain: Design, Analysis, Evaluation and Prospects*. *Journal of Computer Science*, 47(3), 491-524.
- [2] Zhang Z, Zhang B, & Tong X. (2024). *A Blockchain-Based Electronic Complaint Reporting Scheme Using Ring Signatures*. *Computer Applications and Software*, 41(7), 329-335.
- [3] Gao Y, Yao L, Ma Y, & Li F. (2020). *Research on Integrity of Wireless Body Area Network Data Cloud Storage Based on Blockchain*. *Journal of Northeastern University (Natural Science Edition)*, 41(3), 6.
- [4] Hu X, & Shao Y. (2023). *Risk Management Analysis of Intellectual Property Securitization Based on Blockchain Technology*. *Science and Technology Management Research*, 43(23), 204-212.
- [5] Li M, Zhou X, & He J. (2022). *Implementation and Application of Medical Record Electronic Signature Based on Blockchain*. *Chinese Digital Medicine*, 17(8), 74-78.
- [6] Lu R, Wang Z, You J, Cheng L, & Lin X. (2020). *Research on Information Sharing Framework for Railway Engineering Driven by Blockchain Technology*. *Journal of Railway Engineering*, 037(011), 100-105.
- [7] Xu X, & Hou J. (2021). *Study on Technical Solutions to Ensure the Evidentiary Power of Trustworthy Electronic Documents*. *Library and Information Work*, 65(9), 9.
- [8] Guo Y, Jiang W, & Ye S. (2022). *A Regulable Anonymous Transaction System Model in Blockchain*. *Computer Applications*, 42(9), 2757-2764.
- [9] Zheng J, & Lai H. (2020). *A Blockchain-Based Electronic Voting Scheme Using One-Time Ring Signatures*. *Application Research of Computers*, 37(11), 5.