Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 46 No. 5
May 2025

Future Trends in Blockchain-Based Notarization: From Proof of Existence to Full Document Validation

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Abstract

This study examines the promise of blockchain notarization to enhance document validation, security, and efficiency and address challenges like scalability, privacy, and regulatory ambiguity. Emerging technologies like Artificial Intelligence (AI), quantum-resistant cryptography, Zero-Knowledge Proofs (ZKPs), and smart contracts are outlined as principal solutions to the same. AI promotes fraud detection and compliance, quantum-resistant cryptography insulates blockchain against quantum computing attacks, and ZKPs are privacy without compromise on transparency. Smart contracts automate workflows, promoting efficiency across a wide range of industries. Regulatory concerns and scalability remain. Hybrid blockchain architectures, advanced cryptographic protocols, and evolution of global regulatory standards are advised by the study to bridge the challenges and leverage the full capability of blockchain notarization to achieve mass use.

Keywords: Blockchain Notarization, Privacy and Security, Emerging Technologies.

1. Introduction

Blockchain-based notarization is an innovative application of blockchain technology that ensures the integrity and authenticity of documents through decentralized, tamper-proof mechanisms. This system functions by recording a cryptographic hash of a document on a distributed ledger, creating an immutable timestamp that verifies the document's existence at a specific point in time. Unlike traditional notarization processes that depend on central authorities, blockchain-based notarization provides a transparent and secure alternative without single points of failure [1]-[2]. The main intention behind blockchain notarization is the protection of data integrity and authenticity along with nonrepudiation. Such functionalities make it a great device for use in any sector which deals with trust and validation. For example, it helps in the legal field while authenticating contracts and agreements without a chance of forgery [3]. Likewise, in education it secures the release ofcertificates and diplomas against fraud [4]. In the medical industry, the record of the patients is preserved with an enhanced degree of confidentiality and integrity [5]. Financial industry profits from blockchain notarization by providing guarantees over agreement and transaction documents about its authenticity to help speed compliance and audit process [6]. With the advantages also come limitations. While it might guarantee the fact that such a document existed at a specific time and has not changed, the current proof of existence in blockchain notarization cannot validate the actual content of the document nor who created it, let alone if it is adherent to the law or not. This renders it less relevant for those applications where high verifications are required, for instance cross border legal transactions, compliance checking in automated scenarios or business workflow fraud detection [7].

The increasing digitalization of business, legal, and governmental operations requires an even stronger framework that surpasses existence evidence. Document validation that considers the integrity of the contents, context, and its compliance, which can then be separately verified, will be an urgent necessity. It could provide end-to-end trust, facilitate automation, and would make blockchain notarization useful even for high-stakes applications. It involves integrating advanced technologies like artificial intelligence for content analysis, cryptographic advancements for enhanced security, and quantum-resilient systems to provide a future-proofing of threats evolving over time [8].

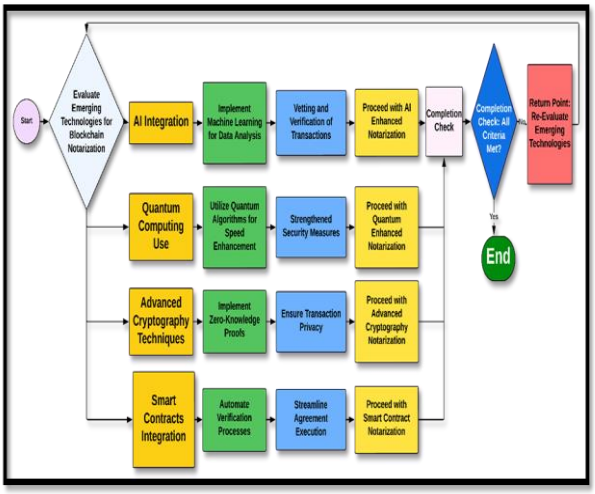

Figure 1. Emerging Technologies Enhancing Blockchain Notarization

This paper examines the evolution of blockchain-based notarization systems, tracing their development from simple proof-of-existence mechanisms to comprehensive document validation solutions. The paper is structured as follows: Section 2 discusses the current state and challenges in blockchain notarization. Section 3 examines emerging technologies, including AI, quantum-resistant cryptography, zero-knowledge proofs, and smart contracts, shaping the evolution of blockchain notarization. Section 4 explores applications in business, legal, and government sectors, while Section 5 delves into ethical, technical, and regulatory challenges, concluding with insights on future directions.

2. Current State and Challenges in Blockchain Notarization

Blockchain technology has emerged as a promising solution for modernizing traditional notarization processes, providing improved security, transparency, and efficiency. This section reviews significant contributions to the field, discussing key methodologies, challenges, and future directions.

[14] proposed a blockchain-based framework for notarial offices that utilized Hyperledger Fabric to facilitate document verification with improved data security. This system would reduce inefficiencies like paper dependency and human errors by using smart contracts to automate notarization workflows and utilizing decentralized ledgers. Further, encryption mechanisms were implemented to maintain privacy, and off-ledger data handling reduced the load of transactions. The authors showed that they indeed enhanced the processing efficiency and information privacy. However, using permissioned networks diminished the degree of decentralization, which is basically one of the most primary blockchain principles. Additionally, system complexity increased concerns in the context of implementation costs. Hence, the authors proposed examining hybrid blockchain models, capable of combining private blockchain advantages.

[2] extended blockchain notarization by proposing a system called Notarizer, where they used NFTs to represent the notarized documents. The NFT encoded the metadata such as timestamp and cryptographic signatures that ensured tamper-proof verification and decentralized ownership. The NFT encoded the metadata such as timestamp and cryptographic signatures that ensured tamper-proof verification and decentralized ownership. Implemented on public blockchains like Ethereum, the system used smart contracts for registering the documents and handling their metadata. The experiments showed strong tamper resistance and correct ownership verification. However, the high transaction costs and energy consumptions were the main bottlenecks. The author recommended integrating layer-2 scaling solutions, such as ZK rollups, to scale significantly and minimize costs. Through this integration, blockchain notarization is merged into digital asset management, yielding a perspective on document integrity. Focusing on collaborative networks, [15] proposed a consortium blockchain model for e-notarization to ensure trust among organizations. Their framework enabled cross-organization document sharing with strict access control mechanisms to ensure that data immutability would be maintained. Performance evaluations presented strong data security and facilitation of trust. But cross-chain communication was also a challenge, and consortium models introduced governance complexities as well. To overcome this, the authors suggested that consideration of decentralized autonomous organizations to improve governance and interoperability be explored.

[16] proposed blockchain framework, NotaryVault, by using Hyperledger Fabric along with the technique of

encryption for safe document authentication. The system had strong tamper resistance and un authorised access even during simulation attacks. But it is revealed that despite its merits towards security, this framework also has scalability problems when computations are scaled with respect to the system. Also, it introduced single points of failure, thereby partially defeating the purpose of decentralization in blockchain. The authors pointed out that distributed encryption techniques would allow breaking through these limitations and lead toward advanced hybrid solutions. [17] considered blockchain notarization during the COVID-19 pandemic. They focused on verification of vaccination certificates and medical records. Their framework was able to ensure tamper-proof data provenance using decentralized storage and smart contracts. It also automated the validation of certificates. Although the outcome showed an improvement in fraud detection, the proof-of-work mechanism used was energy-intensive and unsustainable. The authors suggested a shift to proof-of-stake or delegated proof-of-stake mechanisms that would overcome the energy efficiency challenges. This study demonstrates the practical impact of blockchain notarization in critical scenarios, emphasizing the need for scalable and energy-efficient solutions.

Interoperability challenges are addressed[9], analyzing protocols like atomic swaps and notary schemes across-chain communication in notarization. However, improving security through privacy-preserving protocols like zk-SNARKs had the unfortunate effect of raising high computation costs, making it harder for widespread use. There was a call for an interoperability framework that needed privacy preservation as the author pointed to the use of ZKPs within cross-chain notarization workflows. [10] studied blockchain implementation in the public sector of India, from the perspective of legal and administrative notarization. Case studies on land registries and tax documents showed that the system promoted greater transparency and reduced fraud. However, it still relied on latency and entailed a significant cost to infrastructure, especially in poor resource areas. The authors thus concluded that private blockchains were more secure than the rest; however, scalability proved to be a limiting feature of this technology. They recommended improvements in the scalability of private blockchain to unlock the potential of large-scale public sector applications. [11] synthesized over 100 studies, classified challenges in blockchain notarization into three domains: computational, architectural, and regulatory. Public blockchains had to deal with transaction throughput and energy issues, while private blockchains were concerned about interoperability and reliance on external validators. This overall review pointed out the hybrid blockchain solution to overcome systemic challenges and integrate well into traditional workflows.

Table 1. Key studies and contributions in the blockchain notarization field

Study	Key Contributions	Methodology	Challenges
Gao et al. (2021)	Introduced a blockchain-based framework for notarial offices using Hyperledger Fabric.	Hyperledger Fabric, Smart Contracts	Limited decentralization due to reliance on permissioned networks. High implementation complexity.
Rehaman et al. (2024)	Proposed Notarizer, using NFTs to represent notarized documents with decentralized ownership and tamper-proof verification.	NFTs on Ethereum, Smart Contracts	High transaction costs and energy consumption.
Goulão & Oliveira et al.(2023)	Proposed a consortium blockchain model for e-notarization, enabling cross-organization document sharing.	Consortium Blockchain, Access Control	Cross-chain communication challenges, governance complexities in consortium models.
Dhakade et al. (2024)	Developed NotaryVault, combining encryption and Hyperledger Fabric for secure document authentication.	Hyperledger Fabric, Encryption Techniques	Scalability challenges due to increased computational load, reliance on centralized encryption.
Ahmad et al. (2020)	Focused on blockchain notarization for verifying vaccination certificates and medical records during COVID-19.	Decentralized Storage, Smart Contracts	Energy-intensive proof-of-work mechanisms, scalability challenges.
Haugum et al. (2022)	Analyzed protocols for cross-chain communication in notarization.	Atomic Swaps, zk-SNARKs	High computational costs for privacy-preserving protocols.
Rana et al. (2021)	Examined blockchain adoption in Indian public sector for legal and administrative notarization.	Blockchain in Public Sector	Latency issues, high infrastructure costs, scalability challenges.
Vergidis et al. (2024)	Reviewed over 100 studies and categorized challenges in blockchain notarization.	Systematic Review of Blockchain Notarization Studies	Public blockchains' transaction throughput, private blockchains' interoperability, energy concerns.
Kosmarski et al.(2020)	Explored blockchain adoption in academic recordkeeping for ensuring document integrity.	Blockchain in Academia, Document Integrity	Usability challenges, regulatory barriers.
Mohammad & Vargas et al.(2022)	Reviewed blockchain adoption for certificate notarization in the education sector.	Blockchain in Education, Certificate Notarization	Interoperability issues, resistance from stakeholders.

[12] Discusses blockchain adoption in record-keeping in higher learning, focusing on how the technology can ensure the integrity of documents and lower the overhead of administration. The author claimed that while blockchains reduced tampering risks, usability and regulatory hurdles limited adoption. For academia's to gain widely, they recommended

friendlier interfaces and standardized regulation for blockchain. Similarly, [13] wrote their review on the use of blockchain in education through a focus on certificate notarization. Despite improved data security, interoperability and stakeholder resistance remained as challenges. The authors called for adaptive training programs to demystify blockchain technology and engage stakeholders.

Table 1. summarizes the key contributions of each study, their methodologies, the challenges they encountered. These studies, collectively, bring out the transformative potential of blockchain notarization across different sectors, offering better security, transparency, and automation. From Hyperledger Fabric-based private frameworks [14]-[17] to NFT-driven public blockchain solutions[2], there are methodologies that address specific use cases. However, scalability, energy efficiency, and interoperability remain common challenges. Hybrid models, regulatory harmonization, and accessible frameworks will break open the barriers that face notarization in blockchain to unlock its full potential.

3. Emerging Technologies Shaping Blockchain Notarization

Integration of leading-edge technologies in blockchain systems revolutionizes the process of notarization with respect to increased security, efficiency, and privacy. Ranging from AI to quantum-resistant cryptography, ZKP to smart contracts, it solves all crucial challenges while also opening wider possibilities for application of blockchain. This discussion delves into how these technologies contribute to document validation, fraud detection, and workflow automation, providing a comprehensive overview of their impact.

3.1. AI Integration: Enhancing Document Validation and Fraud Detection

AI transforms blockchain notarization into a more accurate and efficient document validation and fraud detection mechanism. [18] showed how analytics powered by AI can harden financial systems by integrating the machine learning algorithm into the blockchain-based smart contracts. Thus, AI, through its capabilities to automatically detect fraud and ensure identity verification, guarantees real-time monitoring with data integrity, which, in turn, increases confidence in digital ecosystems. Along with this, [19]showed the use of AI-based smart contracts toward compliance activities like KYC and AML processes to emphasize the flexibility and potentiality of AI in adapting the fast-changing pattern of transactions.[20]concentrated on convolutional neural networks for detecting fraudulent activities in digital contracts. This approach would effectively bridge legal safeguards and technological capabilities to provide a robust framework for regulatory oversight. However, issues such as data privacy, scalability, and adversarial robustness have to be addressed in order to unlock the true potential of AI. [27] extended AI's role to dynamic decision-making in notarization workflows, highlighting the need for transparency in AI-driven processes. Together, these studies emphasize the transformative potential of AI in enhancing blockchain's reliability and operational efficiency.

3.2. Quantum Computing: Threats and Advancements in Quantum-Resistant Cryptography

Quantum computing has a huge challenge for the traditional cryptographic mechanisms of blockchain systems; hence, quantum-resistant cryptography is being advanced. [21] presented efficient zero-knowledge proofs using post-quantum cryptographic techniques. Those proofs significantly reduce the size of the proof and are likely to have much improved performance. Their work mitigates a potential vulnerability, enhanced scalability and transaction throughput as well. [22] further proposed lattice-based cryptography and hash-based signatures to harden blockchain systems against quantum attacks in 2024. The said quantum-resistant mechanisms proved quite robust and inflicted negligible delay on transactions, which are favourable in large-scale applications. However, the computational cost associated with such approaches introduces a challenge towards scalability. Thus, such research will throw light on the fundamental need to develop lightweight quantum-resistant protocols for the safeguarding of blockchain technology whose dawn is near in quantum computing.

Table 2. Contributions of emerging technologies in blockchain notarization

Technology	Key Contributions	Methodology	Challenges	Proposed Solutions
AI Integration	Enhances document validation, fraud detection, and identity verification using machine learning algorithms.	Machine Learning, Smart Contracts	Data privacy, scalability, and adversarial robustness.	Improve transparency in AI-driven processes and enhance real-time monitoring.
Quantum-Resistant Cryptography	Secures blockchain systems against quantum computing threats through advanced cryptographic techniques.	Zero-Knowledge Proofs (ZKP), Lattice-based Cryptography	High computational demands, scalability issues.	Develop lightweight quantum-resistant protocols for improved scalability and performance.

Technology	Key Contributions	Methodology	Challenges	Proposed Solutions
Zero-Knowledge Proofs (ZKP)	Enhances privacy-preserving notarization by validating off-chain data without revealing sensitive information.	zk-SNARKs, zk-STARKs, Bulletproofs	Computational efficiency, scalability challenges.	Optimize computational efficiency and integrate ZKP more deeply with smart contracts for better privacy.
Smart Contracts	Automates notarization workflows and ensures secure document validation, with adaptability for dispute resolution.	AI-driven Smart Contracts, Privacy-preserving Protocols	Increased execution times due to cryptographic overhead, transparency concerns in AI-driven decisions.	Improve automation in notarization workflows while addressing compliance and operational challenges.

3.3. Zero-Knowledge Proofs: Privacy-Preserving Notarization

Zero-knowledge proofs have recently become a crucial technological development for improving privacy in blockchain notarization. [23] proposed the design of zk-AuthFeed by integrating zk-SNARKs into smart contracts, which enables the verification of off-chain data, but with privacy preservation. It ensured secure data feeds for notarization operations to achieve scalability for high-frequency operations. [26] applied ZKP to provide privacy-preserving authentication by reducing verification times while ensuring tamper-proof document validation. [24] gave a basic understanding of the ZKP frameworks, and they compared methods such as zk-SNARKs, zk-STARKs, and Bulletproofs. These techniques allow privacy-preserving validation, although computational efficiency is still one of the challenges. The coordination between ZKP and smart contracts, as shown in various studies, points to their potential to improve blockchain notarization by making sensitive information secure while ensuring transparency.

3.4. Smart Contracts: Automating Workflows and Validating Content

Blockchain notarization is characterized by smart contracts, automating workflows and ensuring the safe validation of documents. In real estate transactions, for example, [25] illustrated their potential by incorporating privacy-preserving protocols for property records and ownership transfer management. These smart contracts improved processes, reduced costs, and enhanced transparency at a higher cost in terms of increased execution time resulting from cryptographic overhead. [27] discussed AI-driven smart contracts, which showed its flexibility in adjusting the contract parameters and automating dispute resolution. These advancements increase transaction efficiency but raise questions about the transparency of AI-driven decisions. Smart contracts with privacy-preserving mechanisms and adaptive intelligence enable powerful automation of notarization, dealing with compliance and operational issues. The integration of AI, quantum-resistant cryptography, ZKP, and smart contracts is revolutionizing blockchain notarization by increasing security, privacy, and efficiency. Application of AI in fraud detection and compliance, quantum-resistant cryptography to face emerging threats, the private preserving capability of ZKP, and the automation offered by smart contracts together addresses some of the critical challenges in the digital ecosystem. But it still lacks scalability, computation efficiency, and regulatory harmony. The Table 2. provides a summarization of the contributions, methodologies, challenges, and proposed future directions for each of these emerging technologies within blockchain notarization. Future research must optimize its scalability, explore hybrid models, and ensure that these technologies come abreast of the advancements in the law. All of these difficulties will resolve in order for blockchain notarization to have increased adoption and impact in all varieties of use cases-from finance to property and many other industries.

4. Applications and Future Directions

With their application, blockchain-based notarization systems may be developed to transform most areas into more secure, efficient, and transparent management of documents. It will transform the nature of business processes, raise standards of legal and governmental activities, and create new applications in many fields. The section provides an overview of the most significant business, legal, and governmental use cases for blockchain notarization, as well as forecast future developments.

4.1. Business Applications: Streamlining Contract Management

In the business sphere, blockchain-based notarization systems are going to make contract management significantly better. The automation of document verification and, thus, the minimization of human error in its processes makes blockchain tamper-proof and auditable. It means that smart contracts will automate the execution of already defined terms when specific conditions are met, thereby reducing the usage of intermediaries and making business transactions faster [27] . For example, in the real estate industry, smart contracts can manage property ownership transfer; this process will become faster and more secure [25] . It would be another factor that gives blockchain its decentralized feature: ensuring, with all the parties involved, access to the same immutable version-this brings about an increased level of trust in reducing disputes. Blockchain notarization also has a bright future in supply chain management since it can authenticate transactions between parties in real-time and ensure the authenticity of goods and services [18]. This can be especially impactful in pharmaceuticals, where counterfeit drugs are a significant problem. Blockchain can record and verify each step of the supply chain to mitigate this problem, thus ensuring product integrity and consumer safety.

4.2. Legal and Government Use Cases: Digital Identity Verification and Cross-Border Document Validation

The applicability of blockchain notarization in the legal and governmental sectors, especially in cross-border validation of documents and verification of digital identity, can be very high. For example, in the legal industry, notarization systems improve the validation of documents. Since there would be lesser dependence on paper documents, transactions would be faster, secured transactions. For example, blockchain's transparency and immutability can allow the genuineness of contracts and court orders and even other forms of legal papers to be verified right away, with no chance for tampering or fraud [19]. For government services, blockchain notarization can revolutionize digital identity verification, particularly for citizens' access to government programs or services. Traditional identity verification processes can be slow and susceptible to fraud; however, blockchain allows for secure and decentralized management of personal data, giving citizens more control over their identities [21]. Blockchain technology would help validate documents, such as birth certificates, academic qualifications, and tax records, in cross-border validation, thereby easing international trade, legal proceedings, and migration processes [9]. This way, governments can be sure of the privacy of data held by individuals while being able to authenticate and verify their legal legitimacy [23].

4.3. Predictions: Advancements and Adoption Timelines

It will be more expansive across the industries as blockchain notarization matures further. Acceleration of emerging technologies like artificial intelligence, quantum-resistant cryptography, and zero-knowledge proofs will help the development of more efficient and secure systems [20]-[22]. AI-driven smart contracts will be more and more widely used, further automating workflows and reducing reliance on intermediaries in business and legal contexts [19]. In the broader adoption predictions, within 5-10 years, blockchain notarization systems will be an industry-standard tool in finance, healthcare, and government. The regulatory framework will be developed with advancements in technology; hence, the mainstream implementation of blockchain into legal processes will ensure safer, clearer, and more efficient legal and governmental procedures [11]. However, for such systems, the scalability challenge, energy consumption, and interoperability need to be overcome. Though optimistic, the pace of global adoption might be conditioned by factors like technological maturity, regulatory acceptance, or public trust in blockchain systems.

In conclusion, blockchain notarization is transforming industries by improving the security, efficiency, and transparency of document management. As advancements continue, particularly in AI, quantum-resistant cryptography, and zero-knowledge proofs, blockchain's role in business, legal, and government applications will expand. Addressing the challenges of scalability and regulatory harmonization will be key to unlocking the full potential of blockchain notarization in the near future.

5. Ethical and Technical Considerations

As blockchain technology continues to rework the notarization system, it is significant that ethics and technical challenges be entertained to keep in mind with it. These concerns constitute what it takes to properly introduce the responsible and sustainable integration of blockchain notarization into every aspect.

5.1. Privacy Concerns: Balancing Transparency and Confidentiality

The most paramount of all ethical challenges in blockchain notarization concerns keeping transparency and confidentiality in balance. Blockchain's fundamental feature of immutability makes it ideal for verifying document authenticity and preventing fraud. However, the public nature of many blockchain networks poses privacy risks, especially when sensitive information is involved. For example, personal identifiable information like identification numbers, contract information, and medical record information may be placed within a blockchain for use with legal and governmental purposes. While the transparent nature of blockchain ensures that records may not be altered, failing to handle them correctly has the potential to expose highly sensitive information. These risks have been mitigated through the incorporation of ZKP into blockchain systems so that privacy is maintained but integrity is ensured. A party can prove the truthfulness of some information, but the underlying details of that information remain undisclosed using ZKPs [23]. This technology is necessary for applications such as verification of digital identity, where personal data must remain private but still be validated. Moreover, encryption methods both on-chain and off-chain are critical to protect user information so that only authorized entities can access sensitive documents [16]. Balancing privacy with the intrinsic transparency of blockchain technology is a challenge that still continues but is essential in developing trust and adoption.

5.2. Scalability Issues: Energy Consumption and Processing Capabilities

Among the scalability issues for blockchain systems, particularly concerning PoW-based consensus mechanisms, high energy intensity is necessary to compute the resources validating transactions and securing the network, which increases operational costs. In the case of public blockchains, this is more evident in low transaction throughput, leading to congestions that result in delayed transactions and high fees to send transactions [17]. Thus, scalability is another critical issue that must be resolved to achieve notarization system adoption. Several methods try to scale, but at the same time, energy consumption is kept low. For example, the use of PoS or DPoS greatly reduces the environment impact of blockchain networks [17]. Another important layer-2 solution offered by rollups and sidechains is a more efficient, secure transaction processing [2]. These solutions offload some transactions to secondary layers, thus enhancing throughput and reducing the energy footprint. However, these technologies must be refined further so that they can support large-scale, high-frequency notarization applications without sacrificing security or decentralization.

5.3. Regulatory Challenges: Barriers to Adoption Due to Lack of Standardized Regulations

The major challenges ahead of wide adoption of blockchain notarization relate to regulatory impediments. A lack of standardized regulation across the jurisdictions creates an uncertain situation for businesses and government organizations planning to put blockchain-based notarization systems into operation. With unclear guidance, organizations would be deterred from the adoption of blockchain notarization out of fear over compliance with law, liability, and court recognition of blockchain-notarized documents. For blockchain notarization to be used to its fullest potential, there is a need for global regulatory frameworks that account for the uniqueness of blockchain technology, including its immutability and decentralization. There is a need for uniform standards for data privacy, authentication, and cross-border document validation. In addition, industry stakeholders, policymakers, and regulatory bodies must collaborate to establish an enabling environment for blockchain innovation. According to [11], regulatory harmonization will be critical in ensuring smooth integration of blockchain notarization into existing legal and business processes.

The ethical and technical issues in developing blockchain notarization systems are substantial. Although the privacy aspects of such concerns can be covered by sophisticated cryptographic techniques like zero-knowledge proofs, scalability problems of energy consumption and processing power need continued innovations in consensus mechanisms and layer-2 solutions. Meanwhile, the regulatory framework will have to evolve as the blockchain environment demands special regulatory treatment across jurisdictions. By addressing these concerns, blockchain notarization can be a secure, efficient, and widely accepted tool for modernizing document verification processes.

6. Conclusions and Future Directions

6.1. Conclusion

Blockchain notarization is proving to be revolutionary, adding the elements of security and transparency to document verification process effectiveness. Systems such as the Hyperledger Fabric private blockchain and NFT-enabled public blockchain have promising changes towards the automation of processes, as well as assurance about tamper-proofed documents, but still face scaling challenges, energy efficiency challenges, and interoperability, amongst others. All these new technologies, be it AI, quantum-resistant cryptography, and zero-knowledge proofs, not only led to further innovation in capabilities but also resolved issues on privacy and fraud. With their maturity, business, legal, and even government will penetrate blockchain-based notarization.

6.2. Future Directions

1. Hybrid solutions combining public and private blockchain characteristics toward achieving perfect security, openness, and decentralization
2. Research in using AI-driven smart contracts to increase the effectiveness of automatic verification of documents and support intelligent decision making in the processes of notarization.
3. Lightweight and quantum-resistant cryptographic protocols will protect blockchain-based notarizations against the future threats of quantum computing.
4. Improvement in zero-knowledge proof efficiency towards improving the performance of notarization workflows in the high-frequency transaction environment.
5. Advocate for global regulatory frameworks that recognize the unique characteristics of blockchain notarization and ensure cross-jurisdictional compliance.
6. Move towards proof-of-stake or any other energy-expensing consensus protocols that would further assist in making blockchain minimalistic in ecological footprint.
7. Improve interoperability between blockchains. It should ensure seamless and flawless communication with other blockchains, for notarization.
8. Provide standard accessible platforms so that other industries and stakeholders can use blockchain notarization.

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