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Application of Electronic Invoice Based on Blockchain Technology in Accounting Audit in Textile Industry

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ABSTRACT

The textile industry's supply chain is lengthy and complex, encompassing the entire process from the agricultural procurement of natural fibers like cotton and wool to yarn production, fabric processing, and final garment sales. Against this backdrop, accounting audits of electronic invoices face severe challenges, particularly the susceptibility of data to tampering and the difficulty of tracing and linking invoice information to specific batches of fiber products. To address these issues, this study designs and implements a consortium blockchain-based electronic invoice auditing system tailored to the specific needs of the textile technology field. The system employs the PBFT consensus mechanism and an innovative on-chain/off-chain collaborative storage model, where only core credentials such as invoice hashes are stored on-chain to ensure data immutability, while complete invoice data is maintained in an off-chain database for efficient querying. Experimental results demonstrate that the system greatly enhances the security, transparency, and traceability of invoices throughout their lifecycle, enabling synchronized supervision of capital flows and the physical flow of goods (e.g., cotton yarn, fabrics) across the supply chain, which is crucial for verifying raw material origins and achieving sustainable development goals. Despite a trade-off in write performance, its query verification efficiency is nearly equivalent to that of traditional centralized systems, effectively meeting the real-time auditing requirements of the textile industry. This research confirms that the proposed solution provides an efficient and feasible technical pathway for overcoming financial and tax audit challenges in the fields of textile processing and materials science.

KEYWORDS

textile industry, electronic invoice, blockchain, smart contract, yarn

INTRODUCTION

With the deepening of the digital economy, fiscal and taxation systems worldwide are undergoing a profound transformation. In the textile industry—characterized by transaction-intensive operations and lengthy supply chains—ranging from raw material procurement and yarn production to garment sales, the sheer volume of transactions makes the adoption of electronic invoices not only an efficiency upgrade but also an imperative for effective management [1,2]. However, prevailing electronic invoicing systems largely rely on centralized databases, whose inherent security vulnerabilities are further amplified by the textile industry's complex operational scenarios. Risks such as malicious data tampering and invoice forgery or duplicate reimbursement during multi-tier supplier circulation pose serious challenges for corporate accounting audits [3,4].

Blockchain technology, with its decentralized architecture, data immutability, transparent traceability, and self-executing smart contracts, offers a revolutionary solution for building the next generation of trustworthy fiscal and taxation systems. In recent years, academia has widely explored its potential. For instance, Liao et al. [5] demonstrated that blockchain can significantly improve the quality of corporate financial reporting, while Guerar et al. [6] designed an invoice financing scheme resilient to fraud. Although these foundational studies have substantiated blockchain's promise, existing research has predominantly focused on generic models, leaving a gap in addressing the unique financial and operational dynamics of industry-specific sectors such as textiles.

The limitations of these generic solutions become especially pronounced in the textile industry. The sector's supply chain is highly intricate, with invoices issued by upstream raw material suppliers to downstream apparel manufacturers requiring on-chain synchronization for real-time multi-party verification [7–9]. Effective auditing demands not only the authenticity of financial data (invoices) but also their precise matching with physical logistics data (shipping documents), thereby enabling synchronized supervision of capital and goods flows [10]. For example, an invoice for cotton fabric shipped from Xinjiang to Shanghai must be cross-verified against actual transport records. Furthermore, to ensure quality control and consumer protection, electronic invoices at the point of sale may even need to be traceable back to production batch information [11]. Existing generic blockchain solutions generally lack dedicated smart contract models capable of efficiently handling such multi-stage, cross-domain data correlation and verification, representing a clear gap in the current research landscape.

To address this gap, this study develops a blockchain-based electronic invoicing system tailored to the accounting and auditing requirements of the textile industry. The main contributions of this work are twofold: (1) We propose an innovative on-chain/off-chain collaborative smart contract model that effectively links invoice data with production and logistics information, ensuring end-to-end data transparency and consistency across the textile supply chain. (2) We design and implement a prototype electronic invoice auditing system based on a consortium blockchain architecture, conducting a series of rigorous experiments to quantitatively compare its performance with that of traditional centralized database systems in terms of key metrics such as transaction throughput (TPS) and latency. By providing empirical evidence, this study validates the feasibility and efficiency of the proposed blockchain solution for textile industry applications, offering a solid theoretical and practical foundation for its broader adoption.

SYSTEM DESIGN AND METHODOLOGY

To effectively address the unique challenges of electronic invoice auditing in the textile industry outlined in the introduction, we designed a consortium blockchain-based electronic invoice auditing system. This section elaborates on the overall system architecture, consensus mechanism, innovative data storage model, and core smart contract design.

Overall System Architecture

The system adopts a layered architecture to achieve high cohesion and low coupling among modules, ensuring scalability and maintainability (Figure 1).

Application Layer: Provides a graphical user interface (Web/Mobile UI) for end-users such as financial and auditing personnel, supporting operations including invoice issuance, queries, reimbursement, and write-off.

Service Layer: Functions as the core of backend business logic, interacting with the application layer through APIs. It processes business requests, generates invoice JSON data, computes hash values, and orchestrates communication with both the MongoDB database and the blockchain network.

Contract Layer: Comprises the set of smart contracts deployed on the consortium blockchain, forming the trust foundation of the system. It defines the on-chain structure of invoice data, state transition logic, and operational permissions for all participants.

Consensus Layer: Ensures all nodes agree on the order and outcome of transactions. The system employs the practical byzantine fault tolerance (PBFT) consensus mechanism to guarantee rapid transaction finality and high reliability.

Network Layer: Consists of a peer-to-peer (P2P) network formed by nodes of participating entities (e.g., textile enterprises, tax authorities, and auditing agencies), responsible for transaction broadcasting and block synchronization.

Data Layer: Implements an on-chain/off-chain collaborative storage model, separating invoice "fingerprints" (hashes) from the complete data to balance immutability with system performance.

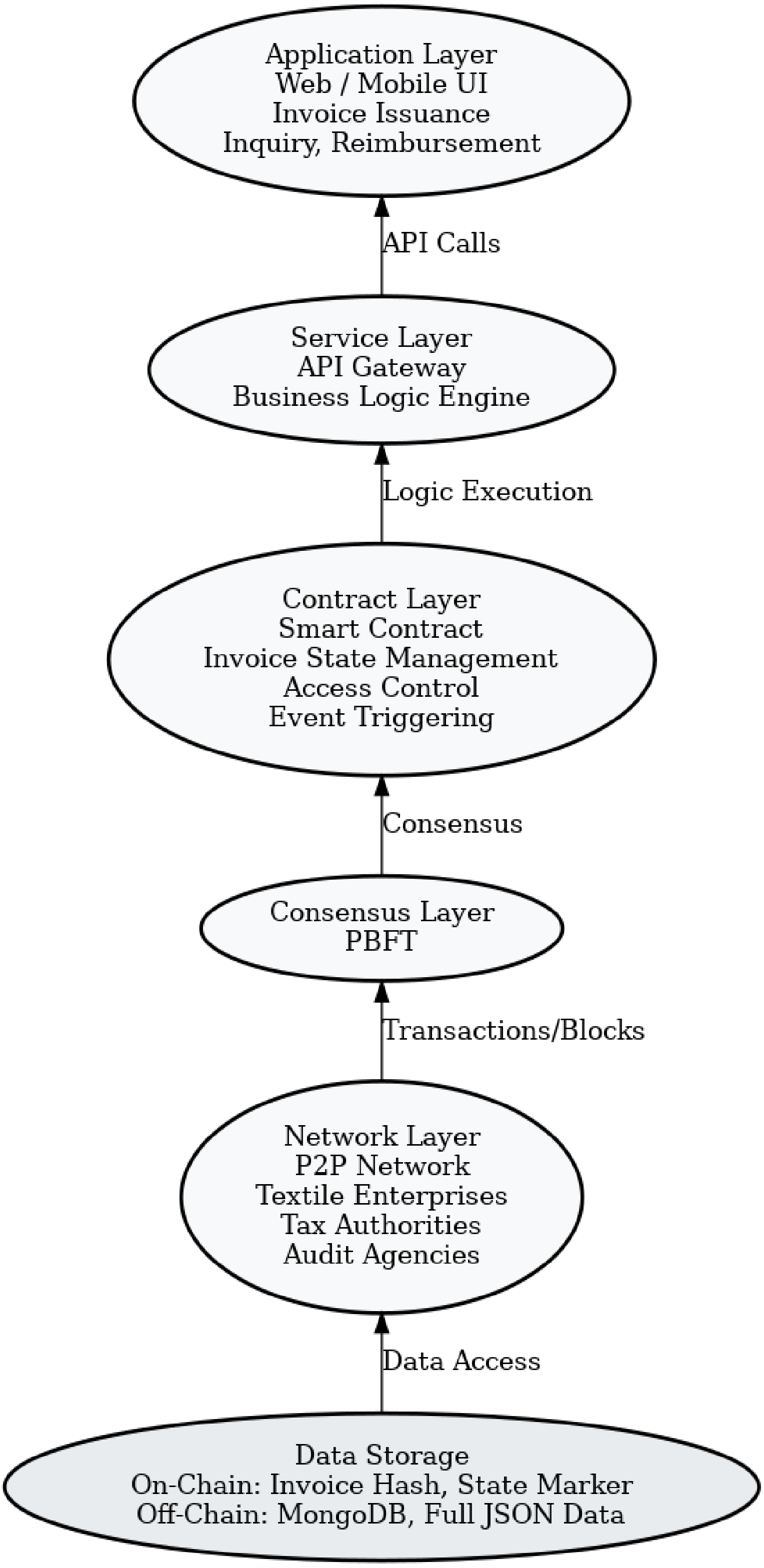

Figure 1. Overall system architecture diagram

Consensus Mechanism: Practical Byzantine Fault Tolerance (PBFT)

Given that the proposed system operates within a consortium blockchain environment with access control requirements and involves high-frequency financial transactions, we adopt PBFT as the consensus algorithm. Compared with PoW or PoS, which are commonly used in public blockchains, PBFT offers several key advantages:

Transaction Finality: PBFT achieves consensus within seconds. Once a transaction is confirmed, it cannot be reversed or lead to blockchain forks, ensuring finality, a critical feature for the determinism required in financial auditing.

High Performance: PBFT does not rely on computationally intensive mining, and its communication complexity is relatively low. It supports high transaction throughput (TPS) and low latency, meeting the performance demands of enterprise-grade applications.

Fault Tolerance: PBFT can tolerate up to one-third of network nodes being malicious or faulty, providing robust security for a multi-stakeholder consortium blockchain.

On-Chain/Off-Chain Collaborative Data Storage Model

To balance the immutability of blockchain data with the efficiency of storage and querying, we designed an on-chain/off-chain collaborative data storage model.

Off-Chain Storage: Complete invoice data is stored in a MongoDB database in JSON format, including all details such as buyer and seller information, itemized goods (name, specifications, quantity, unit price), total amount, tax rates, and notes. MongoDB was chosen for its flexible document-oriented model, which is well-suited for complex and variable invoice structures.

On-Chain Storage: Only essential credential data is recorded on the blockchain:

Invoice Hash: A unique digital fingerprint of the complete invoice JSON, generated via the SHA-256 algorithm.

Key Indices: Critical metadata such as invoice ID, issuer address, recipient address, and timestamp for fast on-chain retrieval.

State Flag: An enumerated value indicating the invoice's current lifecycle state, e.g., Issued, Reimbursed, or Voided.

Data Verification Workflow: When verifying the authenticity and integrity of an invoice, the system executes the process illustrated in Figure 2:

1. An audit or query request is initiated via the application layer.
2. The service layer retrieves the full invoice JSON from MongoDB using the invoice ID and fetches the corresponding on-chain credentials, especially the `invoice Hash`.
3. The service layer recalculates the SHA-256 hash of the retrieved JSON locally.
4. The recalculated hash is compared against the “invoice hash” stored on-chain.
5. A perfect match confirms that the invoice data has remained unaltered since being anchored on the blockchain; any discrepancy triggers an alert, indicating that the off-chain data may have been tampered with. The entire verification process can be completed within milliseconds.

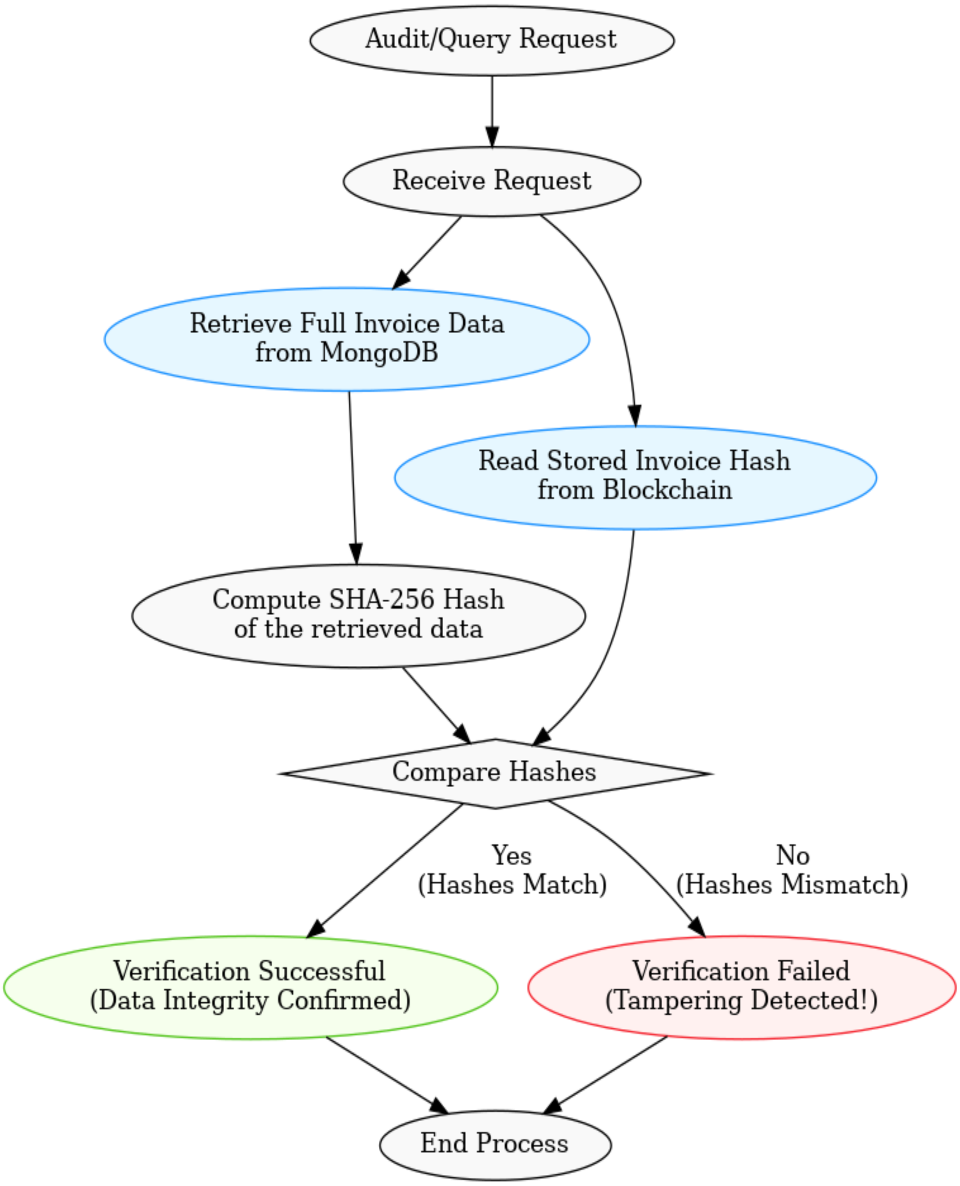

Figure 2. Invoice authenticity verification workflow diagram

Smart Contract Design

Smart contracts form the core of the system’s automation and trustworthy auditing capabilities. We developed a contract architecture centered around the invoice contract.

State Machine Model: The lifecycle of each invoice is abstracted as a state machine, with the following key states defined:

Solidity// Solidity Pseudo-code enum State { None, Issued, Reimbursed, Voided }

Core Functions and Logic: The smart contract enforces strict access control through modifiers, ensuring that only authorized roles (e.g., issuer, auditor) can execute specific operations.

(1) Invoice Issuance

// Pseudo-code for issuing an invoice function issueInvoice (string memory invoiceId, address buyer, bytes32 invoiceHash) public onlyIssuer returns (bool) {// 1. Verify that the invoice ID does not already exist require(invoices[invoiceId]. state == State. None, "Invoice already exists."); // 2. Store the core credential data on-chain invoices[invoiceId] = Invoice ({id: invoiceId, issuer: msg.sender, buyer: buyer, hash: invoiceHash, state: State. Issued, timestamp: block.timestamp }); // 3. Emit an event to notify off-chain services emit InvoiceIssued (invoiceId, msg.sender, buyer); return true; }

(2) Reimbursement Confirmation (markAsReimbursed)

// Pseudo-code for marking an invoice as reimbursed function markAsReimbursed (string memory invoiceId) public onlyFinancialStaff returns (bool) { Invoice storage invoice = invoices[invoiceId]; // 1. Verify that the invoice exists and is in the "Issued" state require (invoice.state == State.Issued, "Invoice not in 'Issued' state."); // 2. Update the invoice state to "Reimbursed" invoice.state = State.Reimbursed; / 3. Record the operation and emit an event emit InvoiceStateChanged(invoiceId, State.Reimbursed, msg.sender); return true;}

Through this design, the core lifecycle management of invoices is codified within immutable smart contracts, effectively eliminating the risks of duplicate reimbursement and data tampering. This provides a robust and trustworthy foundation for accounting audits in the textile industry.

EXPERIMENTAL RESULTS AND ANALYSIS

To validate the effectiveness and performance of the proposed consortium blockchain-based electronic invoice auditing system, we established an experimental environment and conducted a multi-dimensional performance comparison against a functionally equivalent traditional centralized system (implemented using a Node.js + PostgreSQL architecture).

Experimental Setup

Hardware Environment: All tests were conducted on identical cloud servers, each configured with an eight-core Intel Xeon CPU, 16 GB RAM, and a 500 GB NVMe SSD.

Software Environment:

Operating System: Ubuntu Server 20.04 LTS

Blockchain Nodes: Geth v1.10.25

Consensus Mechanism: PBFT (realized via Geth's Clique PoA engine for rapid block generation)

Off-Chain Database: MongoDB v5.0

Centralized System Database: PostgreSQL v14.2

Application Layer: Node.js v16.14

Network Configuration: The consortium blockchain comprised four nodes representing suppliers, manufacturers, employees, and auditing agencies within the textile industry. Nodes were connected via an intranet with <5 ms latency. The centralized system was deployed on a single server with identical specifications.

Test Workload: The JMeter tool was used to simulate varying levels of concurrent users (50, 100, 150, 200), applying stress tests to the core functions—invoice issuance and invoice verification—in both systems.

Performance Evaluation Results

Transaction Throughput (TPS)

Transaction throughput, a key indicator of a system's capacity for handling write operations such as invoice issuance, was measured under different levels of concurrent user load. As evident from Table 1 and Figure 3, the centralized system demonstrates significantly higher transaction throughput compared to the blockchain-based system. This higher throughput is because write operations in the centralized architecture are completed within a single database, whereas every transaction in the blockchain system must undergo a consensus process among nodes—including broadcasting, verification, replication, and synchronization—inevitably introducing additional latency. Nevertheless, the TPS of the proposed blockchain system remains stable at approximately 138 even under a 200-user load, which is sufficient to meet the routine operational demands of most enterprise-level textile business scenarios.

Table 1. Comparative transaction throughput (TPS) of the two systems under varying numbers of concurrent users

Number of Users	Blockchain System	Centralized System
50	85.6	1850.4
100	121.3	2435.1
150	135.8	2610.9
200	138.2	2655.3

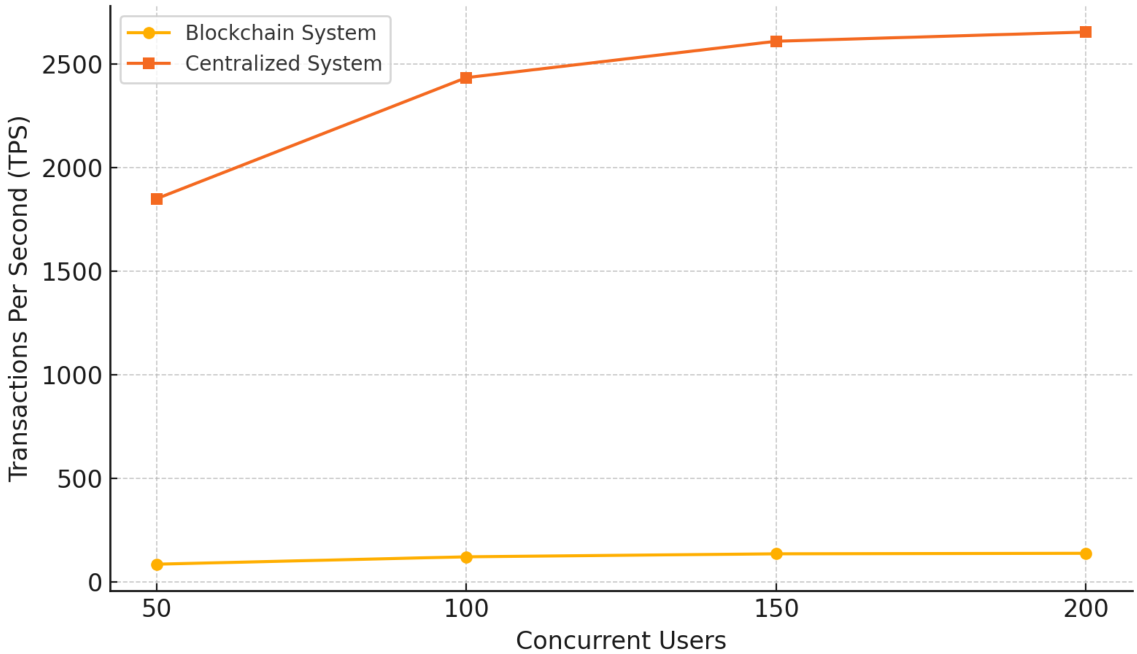

Figure 3. TPS comparison under different concurrent users

Transaction Latency

Transaction latency refers to the time elapsed from the submission of an “invoice issuance” transaction to its final confirmation, directly influencing the user experience. As shown in Table 2 and Figure 4, the blockchain-based system exhibits significantly higher latency compared to the centralized system. Under a 200-user concurrent load, the blockchain system records an average latency of approximately 2.1 seconds, whereas the centralized system achieves about 75 milliseconds. This disparity primarily arises from the block generation interval and the consensus confirmation process inherent in blockchain networks. Although latency is comparatively higher, a confirmation time on the order of seconds remains fully acceptable for this category of near-real-time financial document transactions. In exchange, users benefit from guaranteed transaction finality and immutable auditability.

Table 2. Comparison of average transaction latency (ms) under varying levels of concurrency

Number of Users	Blockchain System (ms)	Centralized System (ms)
50	1250.5	27.0
100	1580.2	41.1
150	1860.8	57.5
200	2110.4	75.3

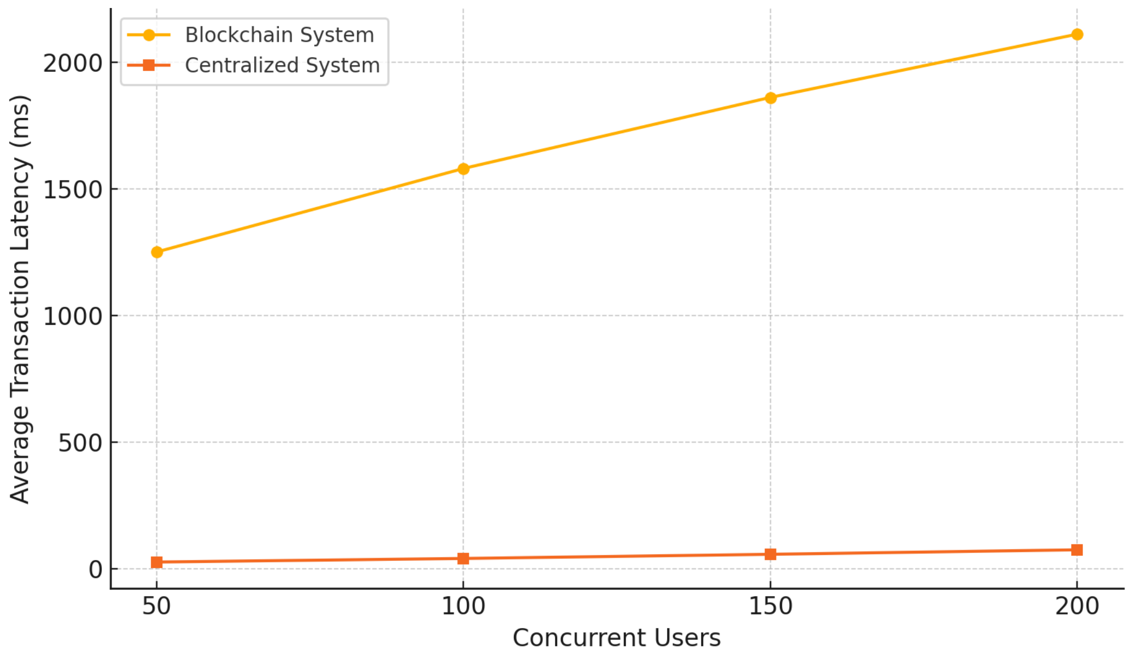

Figure 4. Latency comparison under different concurrent users

Query Verification Performance

Query verification performance refers to the efficiency of executing the “invoice authenticity verification” operation. As shown in Table 3, the proposed system demonstrates robust performance in this regard, benefiting from its collaborative on-chain/off-chain storage architecture. Although the verification process requires an additional retrieval and comparison of the on-chain hash value, the overhead introduced is minimal. On average, the blockchain system's verification latency is only about 37 milliseconds slower than that of the centralized system. This indicates that the proposed design maintains the high storage and query performance required for real-time auditing while ensuring data integrity and trustworthiness.

Table 3. Comparison of average execution time (ms) for invoice query verification

System Type	Average Query Verification Time (ms)
Blockchain System	55.8
Centralized System	18.2

DISCUSSION

This study set out to design and validate a blockchain-based electronic invoicing system tailored to the complex auditing requirements of the textile industry. Our experimental results clearly reveal the intrinsic trade-off between performance and security when introducing blockchain technology, while also confirming the effectiveness of our on-chain/off-chain collaborative model in targeted application scenarios.

A key finding of our experiments is that, compared with traditional centralized systems, the proposed blockchain system exhibits lower TPS and higher latency when processing write-intensive operations such as invoice issuance. This outcome is fully consistent with the expectations of distributed systems theory. The efficiency of centralized systems stems from the simplicity of single-point writes, whereas blockchain's "performance sacrifice" represents the necessary cost of its core value: trust through decentralization [12–14]. Each invoice recorded on-chain must pass through the PBFT consensus process involving broadcasting, validation, and confirmation by multiple nodes. This distributed consensus ensures data immutability and final consistency, fundamentally eliminating the risks of single points of failure and malicious tampering inherent in centralized databases. Notably, despite the performance gap, our system sustains approximately 138 TPS and a latency of about 2.1 seconds under a load of 200 concurrent users. For the textile industry, where invoice issuance is a non-real-time-critical operation, these performance levels are both practical and acceptable. They demonstrate that, within a consortium blockchain framework, selecting an appropriate consensus mechanism (PBFT) allows for trust guarantees unattainable with traditional technologies without unduly compromising performance.

Another major contribution of this study is the validation of the efficiency of the on-chain/off-chain collaborative storage model in audit query scenarios. As the experimental results show, the system's query verification time (≈55.8 ms) is only marginally slower than that of the centralized system (≈18.2 ms). This finding effectively challenges the prevalent notion that "blockchain queries are inherently slow" [15,16]. By storing only the digital fingerprint (hash) and key indices of invoices on-chain while keeping the complete invoice data in a high-performance off-chain MongoDB database, we successfully combined the trust guarantees of blockchain with the fast query capabilities of traditional databases. Auditors and systems can perform near-instantaneous cross-checks between off-chain data and on-chain credentials. This design not only addresses blockchain's well-known "storage dilemma"—its unsuitability for storing large files due to high costs—but also ensures that response times remain uncompromised in high-frequency read and verification scenarios [17–19]. This holds significant practical implications for accounting audits, which often require large-scale, rapid spot checks of invoices.

The system was originally conceived to address the specific auditing challenges highlighted in the introduction. Our smart contract model, which anchors invoice states (e.g., issued, reimbursed) on-chain and binds them to the digital identities of participating entities (e.g., suppliers, manufacturers), establishes a robust technical foundation for complex supply chain traceability. For example, the hash of an invoice representing a particular batch of cotton fabric can be linked in a higher-level "supply chain state contract" with the hashes of its corresponding shipping documents and quality inspection reports. This linking allows auditors not only to verify the authenticity of individual invoices but also to trace their complete lifecycle across the supply chain with a single operation, effectively mitigating deep-seated audit risks such as invoice–shipment discrepancies and fraudulent transactions, capabilities beyond the reach of conventional electronic invoicing solutions.

Compared with prior work by Liao et al. [5] and Guerar et al. [6], which primarily demonstrated blockchain's potential to enhance financial reporting quality and security in invoice financing at a macro level, our study examines a specific industrial domain—the textile sector—and presents a deployable, empirically validated solution addressing its operational pain points. By conducting a quantitative performance comparison, we provide concrete answers to two key questions often overlooked in existing research: "What is the performance cost of introducing blockchain in a specific business context?" and "How can system architecture be designed to minimize this cost?" This contribution fills a critical gap in applied blockchain research.

CONCLUSIONS

This work addresses the key challenges of electronic invoicing in textile industry accounting audits—namely, vulnerability to data tampering and difficulty in supply chain traceability—by designing, implementing, and validating a dedicated consortium blockchain-based electronic invoice auditing system. The core conclusion of this research is that, with careful architectural design, particularly the adoption of the PBFT consensus mechanism and an innovative on-chain/off-chain collaborative storage model, constructing a trustworthy fiscal auditing solution that guarantees data security and integrity while meeting industry performance requirements is possible.

Our primary findings are as follows. First, compared with traditional centralized systems, blockchain systems do incur performance overheads in write operations such as invoice issuance, reflected in lower TPS and higher latency. However, we regard this trade-off as the necessary cost of obtaining blockchain's revolutionary security advantages, including data immutability and transparent traceability. Second, our proposed on-chain/off-chain collaborative storage model proves to be highly efficient, delivering query verification performance nearly indistinguishable from that of centralized systems. This demonstrates the model's effectiveness in balancing security with query efficiency. Overall, the system's performance characteristics align well with the textile industry's non-real-time-critical transactional profile, confirming its feasibility for real-world deployment.

Despite these promising results, the study has certain limitations. The experiments were conducted in a controlled simulation environment rather than under large-scale, real-world enterprise conditions. We also did not examine in depth the complexities of integrating the system with existing enterprise resource planning (ERP) solutions.

Future research could proceed in several directions: (1) pilot deployments in actual textile enterprises to assess stability and usability under real business loads; (2) development of standardized API interfaces to enable seamless integration with mainstream ERP software; and (3) exploration of advanced cryptographic techniques such as zero-knowledge proofs to further enhance the privacy of sensitive business data while maintaining auditability, thereby laying the groundwork for a more secure, efficient, and robust next-generation industrial fiscal infrastructure.

Author Contributions

Hui Chi and Siqi Wu designed the study; all authors conducted the study; Hui Chi and Siqi Wu collected and analyzed the data. Siqi Wu and Hui Chi participated in drafting the manuscript, and all authors contributed to critical revision of the manuscript for important intellectual content. All authors gave final approval of the version to be published. All authors participated fully in the work, took public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or completeness of any part of the work were appropriately investigated and resolved.

Conflict of Interest

The authors declare no conflict of interest.

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Availability of Data and Materials

The datasets used and/or analysed during the current study were available from the corresponding author on reasonable request.

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REFERENCES

[1] Ahmed WAH, MacCarthy BL. Blockchain-enabled supply chain traceability in the textile and apparel supply chain: A case study of the fiber producer, Lenzing. Sustainability. 2021; 13(19):10496.

[2] Penttinen E, Hallikainen P, Salomäki T. Implementing electronic invoicing in a textile and cleanliness company–Impacts on buyer-seller relationships. Journal of Information Technology Research (JITR). 2010; 3(1):28-42.

[3] Yang X, Zhang Y, Wang S, Yu B, Li F, Li Y, et al. LedgerDB: A centralized ledger database for universal audit and verification. Proceedings of the VLDB Endowment. 2020; 13(12):3138-3151.

[4] McMillan EJ. Policies and Procedures to Prevent Fraud and Embezzlement: Guidance, Internal Controls, and Investigation. Hoboken, NJ, USA: John Wiley & Sons; 2006.

[5] Liao K, Lin L, Sun Y. Blockchain adoption and corporate financial reporting quality. Journal of Accounting and Public Policy. 2025; 49:107265.

[6] Guerar M, Verderame L, Merlo A, Migliardi M. Blockchain-based risk mitigation for invoice financing. Proceedings of the IDEAS 19-the 23rd International Database Engineering & Applications Symposium; 10-12 June 2019; Athens, Greece. New York, NY, USA: Association for Computing Machinery; 2019. p. 1-6.

[7] Agrawal TK, Sharma A, Kumar V. Blockchain-Based Secured Traceability System for Textile and Clothing Supply Chain. In: Thomassey S, Zeng X, editors. Artificial Intelligence for Fashion Industry in the Big Data Era. Springer Series in Fashion Business. Singapore: Springer; 2018. p. 197-208.

[8] Rusinek MJ, Zhang H, Radziwill N. Blockchain for a Traceable, Circular Textile Supply Chain: A Requirements Approach. Software Quality Professional. 2018; 21(1):4.

[9] Hader M, Tchoffa D, El Mhamedi A, Ghodous P, Dolgui A, Abouabdellah A. Applying integrated Blockchain and Big Data technologies to improve supply chain traceability and information sharing in the textile sector. Journal of Industrial Information Integration. 2022; 28:100345.

[10] Jamithireddy NH. Blockchain Based Supply Chain and Finance Reconciliation Frameworks in SAP Environments. Research Briefs on Information and Communication Technology Evolution. 2024; 10:190-210.

[11] Westerkamp M, Victor F, Küpper A. Blockchain-Based Supply Chain Traceability: Token Recipes Model Manufacturing Processes. Proceedings of the 2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData); 30 July 2018-3 August 2018; Halifax, NS, Canada. New York, NY, USA: IEEE; 2018. p. 1595-1602. https://doi.org/10.1109/Cybermatics_2018.2018.00267

[12] Islam S, Apu KU. Decentralized vs. Centralized database solutions in blockchain: advantages, challenges, and use cases. Global Mainstream Journal of Innovation, Engineering & Emerging Technology. 2024; 3(4):58-68.

[13] Kalajdjieski J, Raikwar M, Arsov N, Velinov G, Gligoroski D. Databases fit for blockchain technology: A complete overview. Blockchain: Research and Applications. 2023; 4(1):100116.

[14] Carvalho A, Merhout JW, Kadiyala Y, Bentley II J. When good blocks go bad: Managing unwanted blockchain data. International Journal of Information Management. 2021; 57:102263.

[15] Zhang Q, He Y, Lai R, Hou Z, Zhao G. A survey on the efficiency, reliability, and security of data query in blockchain systems. Future Generation Computer Systems. 2023; 145:303-320.

[16] Aliyev AG. Study of Development Trends and Application Risks of Cryptocurrency and Blockchain Technologies in the Digital Environment. Informatica Economica. 2022; 26(3):37-49.

[17] Wang Y, Wang H, Cao Y. Comprehensive Review of Storage Optimization Techniques in Blockchain Systems. Applied Sciences. 2025; 15(1):243.

[18] Heo JW, Ramachandran GS, Dorri A, Jurdak R. Blockchain Data Storage Optimisations: A Comprehensive Survey. ACM Computing Surveys. 2024; 56(7):1-27.

[19] Asiamah EA, Keelson E, Agbemenu AS, Tchao ET, Adjaidoo TS, Klogo GS. Optimizing Blockchain Querying: A Comprehensive Review of Techniques, Challenges, and Future Directions. IEEE Access. 2024; 12:196282-196305.