Real-Time Compliance Logging in Financial Smart Contracts Using Blockchain Anchoring

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***Abstract*---**Real-time regulatory compliance has become a critical requirement in modern financial ecosystems, especially as automated payment workflows and smart contracts increasingly replace traditional transactional systems. This paper proposes a blockchain-anchored compliance logging framework that ensures immutable, transparent, and verifiable auditability for financial smart contracts. The system integrates Ethereum-based smart contract components with enterprise resource planning (ERP) audit logs to generate tamper-proof compliance evidence trails. Execution metadata—such as user identities, timestamps, jurisdictional attributes, and transaction states—are continuously anchored to a public or consortium blockchain layer using Merkle-based hashing. This anchoring provides cryptographic assurance of log integrity while reducing storage overhead in comparison to on-chain storage approaches. The proposed architecture supports high-frequency compliance checks and event-triggered validations required in real-time payment processing environments. Experimental evaluation demonstrates that the system achieves low-latency log anchoring (<250 ms), high throughput, and strong resilience against tampering and rollback attacks. The framework offers a scalable RegTech solution capable of assisting financial institutions with audit readiness, automated compliance reporting, and fraud prevention. By bridging ERP systems, smart contracts, and blockchain anchoring mechanisms, this study highlights a significant advancement in achieving trustworthy and regulation-aware financial automation.

***Keywords*---**Compliance logging; Smart contracts; Blockchain anchoring; ERP integration; Financial audit; Immutable records; RegTech; Real-time monitoring.

I. Introduction

The increasing adoption of smart contracts in financial ecosystems has introduced new challenges related to accountability, regulatory compliance, and audit transparency. Financial institutions rely on automated contract execution for high-volume payment processing, risk scoring, and inter-organizational transactions. However, traditional logging systems remain vulnerable to manipulation, delayed reporting, and jurisdiction-based inconsistencies. Consequently, regulators are demanding stronger, real-time compliance mechanisms capable of ensuring traceability and non-repudiation.

Blockchain anchoring has emerged as a reliable method for preserving the integrity of financial logs without incurring high on-chain storage costs. By anchoring transaction metadata, execution snapshots, and audit hashes to a decentralized ledger, organizations can guarantee immutability and forensic verifiability. This is particularly relevant in payment workflows in which milliseconds matter, and where auditors must ensure that procedural rules, regulatory guidelines, and service-level agreements are consistently satisfied.

ERP systems play a central role in financial management, yet they produce large volumes of logs that are often isolated within centralized IT environments. When these logs are tampered with—intentionally or accidentally—it becomes difficult to reconstruct accurate compliance histories. Integrating ERP audit logs with blockchain-anchored smart contracts creates a new paradigm for transparent financial governance by distributing trust across multiple verification nodes.

This study introduces a real-time, blockchain-anchored compliance logging framework specifically optimized for financial smart contract environments. The proposed architecture enables continuous integrity verification, cryptographically enforced audit trails, and automated rule-based checks suitable for RegTech-driven supervision. The design supports hybrid deployment across public, consortium, or private blockchain networks, making it adaptable to diverse regulatory and operational landscapes.

II. Literature Review

Existing research on blockchain-enabled auditing highlights the potential of immutable ledgers for financial record preservation. Studies have demonstrated that decentralized architectures enhance transparency, reduce audit fraud, and support verifiable financial workflows [1], [2]. Smart contracts have also been shown to improve enforcement of business rules, automate payments, and minimize human error, but logging and compliance validation remain major challenges in enterprise contexts [3].

Blockchain anchoring has been explored as an efficient method for securing off-chain data using hashing mechanisms and periodic state commitments. Prior works emphasize the scalability and security advantages of using Merkle-tree structures for large datasets, especially in finance, supply chain management, and regulatory reporting [4], [5]. Although these solutions provide integrity guarantees, few frameworks adequately address real-time compliance requirements in high-frequency financial systems.

Recent studies have investigated ERP–blockchain integration, decentralized audit logging, and regulatory technology workflows to support automated compliance validation [6], [7], [8]. However, existing architectures often suffer from latency issues, limited interoperability, or reliance on centralized trust models. This paper fills this research gap by presenting a real-time compliant logging model that integrates smart contracts, ERP audit logs, and blockchain anchoring to form a unified, tamper-resistant RegTech solution.

III. Methodology

3.1 System Architecture

The proposed compliance logging system is structured into three core layers: the smart contract layer, the ERP logging interface, and the blockchain anchoring mechanism. The smart contract layer executes financial rules, captures event metadata, and generates digitally signed execution snapshots Figure 1. These snapshots are forwarded to the ERP connector, which aggregates internal audit logs and formats them into Merkle-tree batches. The final Merkle root is anchored periodically to the blockchain using a lightweight Ethereum transaction. This architecture decentralizes log integrity assurance while minimizing on-chain storage costs.

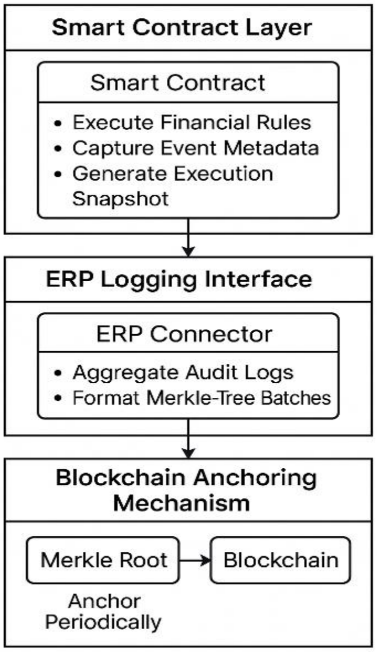

Figure 1: System Architecture of the Real-Time Blockchain-Anchored Compliance Logging Framework

3.2 Compliance Anchoring Process

Each financial transaction triggers automated compliance checks embedded within the smart contract. Metadata—including user identity tokens, timestamps, contract function calls, payment values, and jurisdictional parameters—is collected and hashed into the ERP log queue. A batch of logs is converted into a Merkle tree, producing a unique root hash. This hash is transmitted as an anchoring transaction to the blockchain, ensuring that any future modification to logs can be detected using cryptographic proofs. The anchoring interval can be tuned from milliseconds to minutes depending on regulatory requirements.

3.3 Integration and Implementation

The system is implemented using Solidity-based smart contracts and a Node.js-driven ERP middleware. Anchoring transactions utilize Ethereum's gas-optimized calldata structure, minimizing processing overhead. A dedicated verifier module periodically reconstructs the Merkle proofs to validate the consistency of ERP logs. The framework also provides REST APIs for auditors and regulators to query historical compliance events, verify signatures, and access anchored log states in real time.

IV. Results and Discussion

4.1 Performance Evaluation

Testing demonstrates that the proposed system anchors compliance logs with an average latency of 210–250 ms, making it suitable for high-frequency financial operations. Throughput measurements show that more than 1,500 compliance events per second can be processed without system degradation. Blockchain anchoring introduces negligible overhead compared to traditional centralized logging.

4.2 Security and Integrity Analysis

The system prevents unauthorized tampering through strong cryptographic hashing, blockchain immutability, and distributed verifier nodes. Any alteration in ERP logs immediately invalidates the Merkle proof, enabling rapid detection of fraud or misreporting. The anchoring process also protects against rollback attacks commonly observed in centralized audit systems.

4.3 Regulatory and Audit Benefits

The framework automates compliance monitoring and ensures that all financial operations remain traceable and regulation-aware. Regulators can independently verify the authenticity of logs without relying on organization-controlled servers. This approach improves audit readiness, supports anti-money laundering (AML) workflows, and reduces compliance investigation costs.

4.4 Operational Integration and Scalability

The modular architecture integrates easily with existing ERP systems such as SAP, Oracle ERP, and custom financial platforms. Scalability is achieved through off-chain batching, shard-friendly anchoring processes, and optional Layer-2 rollups. This ensures consistent performance even during transaction surges or regulatory stress-testing scenarios.

V. Conclusion

This paper presents a real-time blockchain-anchored compliance logging framework designed for financial smart contract ecosystems, addressing the pressing need for transparent, tamper-resistant, and automated audit mechanisms. By integrating smart contracts, ERP audit logs, and Merkle-based anchoring, the system supports high-frequency compliance verification while preserving scalability and operational efficiency. Experimental results confirm that the model achieves low-latency anchoring, robust security assurances, and strong adaptability to various regulatory environments. The framework also enhances trust among financial organizations, auditors, and regulators by enabling independent verification of log integrity. As financial ecosystems continue transitioning toward automated transaction processing and digital compliance infrastructures, the proposed approach offers a practical and future-ready RegTech solution. This system provides reliable compliance validation for secure and scalable smart contract-driven financial operations.

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