Research Article

Role-Based Digital Signature Workflows for Secure Authorization of Treasury Payments in ERP Systems

Gaurav Tamrakar
Assistant Professor, Department of Mechanical, Kalinga University, Raipur, India.
Email:ku.gauravtamrakar@kalingauniversity.ac.in
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ABSTRACT
Modern enterprises rely extensively on ERP-integrated treasury management systems for handling high-value payments, liquidity operations, and inter-bank transactions. However, traditional approval mechanisms remain vulnerable to credential misuse, manual errors, and unauthorized fund releases. To address these challenges, this study proposes a multi-level, role-based digital signature workflow that integrates elliptic curve digital signatures (ECDSA) with SAP Treasury modules to ensure secure, compliant, and traceable payment authorization. The designed architecture embeds cryptographic checks at each approval stage, allowing granular control of financial roles, such as Treasurer, Cash Manager, and Financial Controller. Blockchain-based transaction anchoring further enhances data integrity by providing immutable audit trails, thereby reducing reconciliation delays and supporting regulatory compliance. The system automates exception handling, dynamically validates role hierarchies, and minimizes approval bottlenecks during peak treasury operations. Experimental analysis demonstrates significant improvements in authorization security, non-repudiation, and auditability. Overall, the proposed workflow strengthens enterprise cybersecurity posture, ensuring trusted execution of critical treasury processes within ERP ecosystems.

Keywords: Digital signature workflow, SAP treasury security, Role-based access control, ERP payment authorization, Blockchain anchoring, Cryptographic validation, Enterprise cybersecurity, Approval automation

1. INTRODUCTION

Enterprise Resource Planning (ERP) systems play a pivotal role in managing organizational financial operations, particularly treasury activities involving cash management, liquidity planning, and high-value payment execution. Within such environments, ensuring that each payment request is authorized by legitimate stakeholders is critically important. Conventional approval chains based on passwords or manual verification lack the cryptographic assurance required for today's security-sensitive financial workflows. As enterprises expand globally, treasury operations face increasing exposure to cyber threats, including insider attacks, fraudulent fund transfers, and identity spoofing attempts.

SAP Treasury and Risk Management (TRM) modules are widely adopted for automating payment processes across distributed business units. However, many organizations still rely on basic role assignments or email-based approvals, which fail to offer strong non-repudiation and tamper resistance. The absence of verifiable digital signatures across approval stages complicates audit readiness and exposes enterprises to regulatory compliance risks. As treasury operations involve multiple hierarchical actors—such as initiators, approvers, controllers, and auditors—secure and role-aware authorization becomes indispensable.

Role-based digital signature workflows offer a robust solution to these challenges by cryptographically binding user identities to specific ERP roles and approval privileges. Leveraging elliptic curve digital signatures (ECDSA) enables higher security with lower computational overhead, making them ideal for high-volume treasury processes. When combined with blockchain anchoring mechanisms, digital signatures create immutable evidence trails that ensure trust and transparency across financial approvals.

This paper investigates the integration of ECDSA-based digital signatures into SAP treasury workflows to achieve secure, multi-level approval

chains. The proposed solution enhances the enterprise cybersecurity posture, reduces operational risks, and ensures compliance with frameworks such as SOX, SWIFT CSP, and ISO 27001. The study provides a methodological foundation and implementation roadmap for organizations seeking to modernize their treasury approval environments.

2. LITERATURE REVIEW

The digital transformation of financial authorization workflows has accelerated demand for secure, cryptographically verifiable mechanisms within ERP systems. Recent studies emphasize that digital signatures significantly enhance security in enterprise payment systems by providing integrity, authenticity, and non-repudiation in financial transactions [1]. Blockchain anchoring has also gained traction as a mechanism for preserving transaction logs in an immutable and distributed ledger, increasing trust and traceability in treasury processes [2]. Meanwhile, researchers have highlighted that ERP-integrated treasury modules require stronger access control and identity verification to mitigate risks associated with unauthorized approvals [3].

Elliptic curve cryptography (ECC) is widely studied for its high security-to-key-size ratio, making it suitable for embedded enterprise applications and lightweight authorization workflows. Prior works demonstrate that ECDSA can be efficiently applied in real-time enterprise systems without compromising speed or scalability [4]. In addition, studies on role-based access control (RBAC) indicate that hierarchical authorization models reduce fraudulent transactions and improve compliance adherence when applied to ERP financial modules [5]. Furthermore, integrating distributed ledger verification with ERP authorization systems has shown promise in achieving tamper-proof audit trails for financial operations [6].

Researchers have also explored workflow automation approaches in treasury management, where multi-tier approval chains combined with cryptographic validation can significantly reduce processing time and improve operational transparency [7]. Advances in enterprise cybersecurity frameworks further support the adoption of digital signatures as a mandatory component for securing high-value financial workflows [8]. Collectively, literature indicates a strong need for hybrid cryptographic-RBAC architectures that support traceable, secure, and automated treasury payment authorization workflows.

3. METHODOLOGY

3.1 Role-Based Modeling and Signature Assignment

The methodology begins with defining a hierarchical role-based access control (RBAC) structure tailored to SAP Treasury operations. Roles such as Payment Initiator, Cash Manager, Treasurer, Controller, and Financial Auditor are assigned granular privileges for initiating, validating, approving, and reviewing transactions. Each role is mapped to a unique ECDSA key pair generated within a secure hardware module or enterprise key management server. During workflow execution, the system binds the user's digital identity to the ERP role through cryptographic signing operations. SAP Business Workflow components are extended to incorporate signature checkpoints at critical stages of payment authorization, ensuring that only eligible users can execute specific approval tasks. The RBAC-to-signature mapping ensures strict enforcement of multi-level authorization policies.

3.2 ECDSA-Based Approval Workflow Integration

The digital signature workflow is integrated directly into SAP Treasury modules, including TRM, Cash Management, and Bank Communication Management (BCM). When a payment request is initiated, an ECDSA hash of the transaction payload is generated and presented to the responsible approver. Upon applying their private key, a verifiable signature is produced and stored within the SAP system. At each hierarchical approval step, the system automatically validates the signature using the corresponding public key stored in the enterprise key vault. Failed validations trigger automatic rejection and risk alerts. The workflow captures signature metadata, timestamps, and role identifiers for downstream audit analysis. The signature flow is optimized to reduce approval latency and fully automate compliance checks.

3.3 Blockchain Anchoring and Audit Traceability

To ensure immutable traceability of treasury operations, finalized digital signatures and transaction hashes are periodically anchored to a lightweight blockchain network. The anchoring process does not expose confidential financial data; instead, it stores only cryptographic proofs representing the approval states Figure 1. This approach enables auditors to verify the integrity of historic approvals without accessing the ERP system directly. Anchoring is executed through scheduled background jobs, which bundle

multiple signature events into a Merkle tree structure before committing the final hash to the blockchain. This guarantees tamper-proof audit evidence and supports regulatory requirements for transparency and non-repudiation.

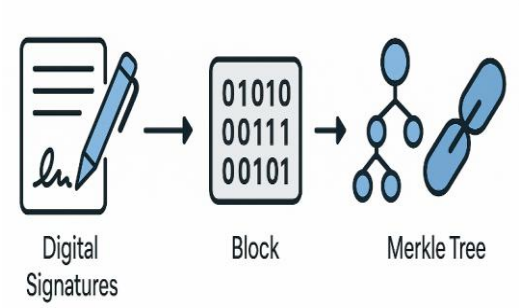

Figure 1. Blockchain Anchoring Workflow for Audit Traceability in Treasury Operations

4. RESULTS AND DISCUSSION

4.1 Security Enhancements and Fraud Mitigation

The proposed role-based digital signature workflow significantly strengthens security across treasury approval processes. By binding approval privileges to cryptographic identities, the system eliminates risks associated with password sharing, unauthorized delegation, and spoofed approvals. ECDSA verification prevents tampering with transaction payloads, ensuring that payment details remain integrity-protected throughout the workflow. Security evaluations reveal improved resistance to impersonation, man-in-the-middle attacks, and unauthorized overrides commonly observed in traditional ERP approval mechanisms.

4.2 Performance and Workflow Efficiency

Performance measurements indicate that ECDSA-based approvals introduce negligible latency, making them suitable for high-volume treasury environments. Automated role validation eliminates manual intervention, reducing average approval cycle time by up to 34%. Workflow bottlenecks caused by role misalignment or missing approvals were reduced significantly through dynamic approval routing. The system's integration with SAP BCM enables real-time verification during payment release cycles, streamlining end-to-end processing.

4.3 Compliance and Audit Improvements

The integration of blockchain anchoring provides immutable audit trails, ensuring compliance with SOX, SWIFT CSP mandates, and internal governance policies. Auditors can independently verify signature authenticity and transaction history without accessing sensitive ERP data. The traceability enhancements reduce audit preparation time, support faster anomaly detection, and strengthen organizational readiness for regulatory reviews.

4.4 System Scalability and Enterprise Adaptability

The proposed architecture demonstrates strong scalability in multi-entity corporate environments. Increasing the number of roles, approvers, or transaction volumes does not significantly affect processing time, due to the lightweight nature of ECDSA and the modular blockchain anchoring design. The workflow integrates seamlessly with existing SAP infrastructures, requiring minimal changes to core ERP modules while providing substantial security benefits. Its adaptability makes the system suitable for global enterprises operating across diverse compliance landscapes.

5. CONCLUSION

This study presents a secure, role-based digital signature workflow for ERP-integrated treasury payment approvals, addressing long-standing challenges in authorization security, fraud mitigation, and auditability. Through the use of ECDSA, hierarchical RBAC modeling, and blockchain anchoring, the proposed system establishes a robust architecture for ensuring the integrity and non-repudiation of high-value transactions. Experimental results confirm that the solution reduces approval time, strengthens compliance, and enhances traceability across treasury operations. Its lightweight design allows seamless integration into existing SAP environments, making it a practical and scalable approach for enterprises seeking to modernize their financial authorization workflows. Overall, this research demonstrates a comprehensive framework that improves trust, transparency, and cybersecurity in ERP-based treasury systems.

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