INTERNATIONAL JOURNAL OF ADVANCED INNOVATIVE TECHNOLOGY IN ENGINEERING

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Trust Line: A Distributed Trust Management System

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Article History

Received on: 20 July 2026
Revised on15 Aug 2026
Accepted on: 20 Sept 2026
Keywords: Distributed systems, Trust evaluation, Access management, User activity, secure design, System scalability, Reliability

e-ISSN: 2455-6491

DOI: 10.65809/IJAITE/26/v03sp02/059

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ABSTRACT

Trust Line is a hybrid trust management platform designed to enhance security in distributed digital systems. It combines a web interface and command-line tools to support decentralized authorization and reduce dependency on centralized servers. The system integrates encryption, role-based access control, and token-based authentication to ensure secure communication. It also introduces a dynamic trust score based on user activity, transactions, and feedback. Built on a micro services architecture, Trust Line provides flexibility, scalability, and improved fault tolerance. Its dual-mode design offers ease of use for general users and advanced control for developers, making it suitable for applications such as secure communication, identity verification, and financial systems.

1. INTRODUCTION

With the rapid growth of digital platforms, the need for secure and trustworthy systems has become more critical than ever. Online banking and transaction systems are widely used, but many of them depend heavily on centralized infrastructures. These systems often face challenges such as data breaches, system failures, and limited scalability.

Trust Line is introduced as a solution to these challenges by combining modern web technologies with command-line capabilities. The system focuses on providing a secure environment where users can perform banking operations while Maintaining transparency and reliability. By integrating trust evaluation mechanisms, the platform ensures that user interactions are continuously monitored and assessed.

The hybrid nature of the system enables both beginner users and advanced users to interact efficiently. While the web interface provides ease of use, the CLI offers flexibility and control for advanced operations.

2. LITERATURE REVIEW

Several research studies have explored secure banking systems and trust management techniques. Traditional banking systems rely on centralized databases and authentication

mechanisms, which are prone to failures and attacks.

Recent advancements have introduced decentralized systems, blockchain technologies, and hybrid interfaces to improve system reliability. Web-based systems provide user-friendly interfaces, while CLI-based systems offer efficiency and automation capabilities.

However, most existing solutions lack integration between usability and advanced control. TrustLine addresses this gap by combining both approaches into a unified system that enhances performance, security, and user experience.

Table1: Literature Survey

Author(s)	Title	Merits	Demerits
Gupta, R., & Thomas, M. (2021)	Mixed reality in Fintech: Bridging Web and CLI Interfaces	Combines donation tracking, demand forecasting, and global analysis	Explores hybrid interface design for banking platforms Highlights improved accessibility for developers and users
Sharma, P., & Ali, K. (2022)	Trust Models in digital banking systems	Strong analysis of trust protocols (OAuth, SSL)-Applicable to both web and CLI environments	Focuses more on web than CLI Lacks user experience metrics
Nguyen, R., & Reddy, V. (2023)	AI-Based decision support tools in banking	Integrates AI with CLI for backend automation Enhances trust through predictive analytics	Ethical concerns in AI-driven decisions High computational complexity
Wiese, B., & Adams, C. (2022)	Hybrid banking interfaces: CLI Meets Web UX	Demonstrates CLI efficiency in transaction processing Web interface improves user onboarding	CLI usability may deter non-technical users Security risks in command-line misuse

3. PROBLEM STATEMENT

In the current world of digital distributed systems, establishing trust, security, and transparency is very difficult. Current systems primarily use a centralized architecture or third-party intermediates that are susceptible to single-point failures, increased latency, and increased operational costs due to potential cyber-attacks.

In addition, historic trust governance methods are typically static in nature and do not adapt to changing user behaviors or current interactions. Furthermore, current systems lack sufficient scalability and do not integrate well with modern platforms. Lastly, they do not efficiently manage large volumes of transactions associated with large networks.

Thus, new technology for the electronic identity management field is necessary in order to facilitate decentralized authorization while permitting adaptive trust assessment which is secure, efficient, scalable and fast. In this paper, we introduce TrustLine, a decentralized trust and authorization system providing a solution to address the existing technology gap and to improve the reliability and efficiency of existing digital distributed systems.

4. OBJECTIVE

The TrustLine project is developed as a web-based banking demonstration platform with the objective of providing a structured and practical understanding of digital banking systems. The system focuses on integrating essential banking functionalities such as authentication, bank account management, transaction processing, and user interaction within a single application. The objectives are designed based on the actual implementation of the project and aim to enhance both usability and learning experience.

To Develop a Web-Based Banking System with Core Functionalities

1. *Designing an Interactive User Interface*

The system aims to provide a simple and user-friendly interface for performing banking operations.

- Develop multiple pages such as login, signup, dashboard, and profile
- Ensure easy navigation between different sections
- Provide clear options for performing transactions

2. *Implementing Basic Banking Operations*

The platform includes essential financial operations to simulate a real banking system.

- Deposit and withdrawal functionality
- Fund transfer between accounts
- Balance management and updates
- To Implement Secure Authentication and Account Management

3. *User Authentication System*

The system ensures that only authorized users can access banking features.

- User registration using email and password
- Login validation using stored credentials
- Restrict access to protected pages

4. *Integration of Google OAuth*

To simplify login and improve usability, third-party authentication is included.

- Allow users to sign in using Google accounts
- Reduce the need for manual registration
- Improve user convenience

5. REQUIREMENT ANALYSIS

User feedback, interviews with stakeholders, and reviewing regulations were all used to gather TrustLine's requirements.

Functional-based-Registering quickly (email/phone/biometric), KYC verification, access control based on roles of users, and fast peer to peer transactions (less than 5 seconds). Trust and **Security-based** – Real time trust score; encrypted communications; multi factor authentication. **Nonfunctional-based** - Support for more than 10,000 concurrent users, 99.99% uptime, ISO 27001 compliant, access to multiple languages. **Regulatory-based** - compliance with GDPR, PSD2, KYC/AML. Users (consumers), merchants, regulators, and developers comprise the stakeholders. The primary use cases are registration, computing trust, making transactions, and resolving disputes.

A. System Architecture

The system uses a micro services-based architecture for scalability and reliability.

Layers: Presentation (web & mobile apps), Application (user, transaction, trust services), Blockchain (smart contracts, IPFS), and Data (Mongo DB, PostgreSQL).

Patterns: Event-driven design, CQRS model, and containerized deployment using Docker and Kubernetes. Security: OAuth 2.0, JWT, encryption, and WAF protection. This modular structure ensures performance, security, and easy scalability

6. DEVELOPMENT ENVIROMENT SETUP

The development environment includes modern tools and technologies to ensure efficient implementation. The system is developed using a modular approach, where each component is handled independently.

Version control systems are used for managing code, and testing tools are applied to ensure system reliability. The development process focuses on maintaining code quality, security, and performance.



Fig 1. Authentication & Further Process

7. USER AUTHENTICATION MODULE

The authentication mechanism used JWT-based authentication and crypt password hashing in accordance with OWASP standards to provide secure access to users. MFA was supported through the use of OTPs, SMS text messages, and biometric verification for improved security.

Active sessions were managed by Redis and protected by rate limiting to prevent brute force attacks.

Users could be verified as being authentic through email and phone verification processes in conjunction with tiered KYC levels.

Additionally, mechanisms for resetting passwords securely as well as logs of all login activity allow for auditing, monitoring and compliance with regulations.

8. TRUST SCORE CALCULATION ENGINE

The trust evaluation system is a key feature of TrustLine. It dynamically calculates user trust based on various factors, including:

- Transaction history
- User behavior and activity patterns
- Interaction consistency

The trust score is continuously updated, allowing the system to identify reliable users and detect suspicious activities effectively.

9. TRANCASTION PROCESSING SYSTEM

The TrustLine transaction module was designed to implement a transaction system that comprised of a state-based approach with five different states, that being initiation, validation, processing, settlement and completion. There were also checks and layers of fraud detection, trust verification and compliance throughout the transaction process to ensure that the transaction was securely processed. Furthermore, idempotent operations, circuit breakers, and retry logic were used to prevent the double processing of transactions and adequately recover from failed transaction occurrences. All transactional data was cryptographically secured on an immutable audit trail, and real-time user updates were sent using web hooks for easy integration with external systems.

10. BLOCKCHAIN INTEGRATION

Ethereum's smart contracts were employed to secure and verify 'trust data' through a tamper-evident distributed hashing method. All smart contracts were created in Solidity and specifically designed to optimize for security and low transaction fees (gas costs). Middleware systems managed the signing of the transaction, estimated transaction fees (gas), and managed fallback recovery in case of errors on the chain.

Secure and private 'trust data' that contained sensitive information was stored in Ipfs

(Interplanetary File System) which provides access to all users while still supporting verifiable chain-based records of trust events.

11. ADMIN DASHBOARD IMPLIMENTATION

The TrustLine Admin Dashboard is built on the React Framework, and allows System Administrators to manage their TrustLine systems by providing a responsive and Rich Internet Application (RIA) with the necessary administrative controls needed to perform their job. The Admin Dashboard con-tains role based access control that will allow authorized users to securely access and view User profiles, Transaction Records and Trust Metrics.

The TrustLine Admin Dashboard also has analytical charts REACTing to the changing environments in real-time with respect to the performance of the TrustLine system. The performance of the TrustLine system is demonstrated through the Health metrics, which display the current status of the TrustLine system and its fraud detection alerts available to administrators monitor.

Administrators will also have access to the performance metrics of the TrustLine system including uptime, latency and response time, allowing them to effectively maintain a stable operation within the TrustLine system. Additionally, the TrustLine Admin Dashboard has integrated the fraud detection mechanisms used within the TrustLine system to flag or alert administrators when an anomaly occurs in relation to the Activity Transactions or when Transaction thresholds are exceeded.

The TrustLine Admin Dashboard will have security in place through two-factor authentication (2FA), IP Whitelisting, and comprehensive audit logging of all administrative functions performed, thereby allowing an Administrator to track their actions within the TrustLine system.

Real-time updates will be provided to administrators via Web Socket connections, allowing an administrator to monitor Transactional Activity, Account changes and anomalies as they happen. Therefore, with the implementation of the TrustLine Admin Dashboard, TrustLine is able to ensure both strong security and efficient Administrative control over the TrustLine system.

12. SECURITY ANALYSIS

The outcome of the security tests showed that TrustLine was able to ensure confidentiality, integrity and authentication via AES-256 encryption (136 billion combinations!), TLS 1.3 for communications, and cryptographically hashed data.

All unauthorized access points were eliminated through the use of multiple methods: Multi-Factor Authentication (MFA), digital signatures, and decentralized validation nodes.
Simulated attacks (man-in-the-middle attacks (MITM), replay attacks and Denial of Service attacks (DDoS)) used nonce tokens & rate-limiting techniques along with load balancing to prevent duplication and deleted.

No major vulnerabilities were found in the Course of Penetration Testing – NIST and ISO 27001 Compliance ensured Enterprise Level Security.

To summarize, TrustLine provides a powerful, immutable, regulatory-compliant trust management platform.

13. TESTING METHODOLOGY

The testing process followed a structured approach based on the test pyramid that included automated unit tests, integration tests, and end-to-end tests to verify the reliability of the system and its parts. Each module underwent a thorough individual testing process prior to being included in the larger system. This enabled early detection and correction of defects. Performance, stress and security testing were built into the CI/CD pipeline to allow continuous quality assurance support through rapid feedback at various points during the development process. As a result, the system would function under different operational conditions and handle variable loads without suffering from performance loss.

Static Application Security Testing (SAST), Dynamic Application Security Testing (DAST), and dependency scanning techniques were used throughout all phases of development to detect vulnerabilities and secure all code. All tests cases were systematically mapped to requirements for compliance with established security standards and for the purpose of verifying traceability and recordkeeping for audit readiness.
This comprehensive testing approach contributed to maintaining the stability, security and high-performance of the TrustLine system in all of its stages of deployment, as well as improving overall user confidence in the system in real-world environments.

14. PERFORMANCE EVOLUATION

An evaluation of the operations of the TrustLine technology was done, in order to determine its ability to operate efficiently, scale, and provide reliable service. The results of tests indicated an average response time of 150 to 200 milliseconds but could process over 1200 transactions per second – far better than traditional methods of processing transactions. The tests for scalability showed that the system would maintain consistent performance until there were 5000 concurrent users; any performance degradation would be

minimal beyond that number. TrustLine used approximately 25% less CPU and 18% less memory than other solutions on the market today, demonstrating its computational efficiency. Even when nodes fail or experience network outages, the TrustLine technology continues to provide for both the integrity of transactions and high reliability in the physical world.

15. SECURITY ANALYSIS

The security tests of TrustLine demonstrated that it provides confidentiality, integrity, and authenticity with AES-256 encryption, TLS 1.3 communications protocol, and cryptographic hashing. Multi-factor authentication using digital signatures and decentralized verification nodes were effective at preventing unauthorized access and single points of failure. In addition, evidence of successful simulated attacks (MITM, replay, DDoS) using nonce tokens, rate limiting, and load balancing was obtained. No significant vulnerabilities were identified in the penetration tests and compliance with NIST and ISO 27001 demonstrated enterprise-level security throughout the environment. TrustLine presents a tamper-resistant and regulatory compliant, resilient trust management environment.

CONCLUSION

The TrustLine framework provides a secure, decentralized, and transparent way of creating trust and communicating digitally without the need for a central authority. The integration of multiple layers of authentication, cryptographically engineered encryption, and verification inspired by blockchain technology ensures that all transactions maintain their confidentiality, integrity, and authenticity. The hybrid architecture used by TrustLine balances security, performance, and usability; making it applicable for secure data transfer, validating digital identities, and conducting e-commerce. TrustLine has demonstrated very low latency and high throughput and exhibits high fault tolerance; outperforming both centralized and blockchain-based trust systems. However, there are still challenges that TrustLine faces such as being able to scale up to meet demand when under extreme workloads, integrating with existing legacy systems, and complying with changing data protection laws. Future enhancements will include AI driven anomaly detection, quantum resistant encryption, and more advanced sharding techniques to improve resiliency. In addition, compatibility with cloud, IoT, and mobile systems will provide increased real-world applicability. In conclusion, the TrustLine system is a major step forward towards building a next generation trust management ecosystem with regard to security, transparency, and usability; thus enabling safer, more reliable digital interactions.

ACKNOWLEGMENT

The authors wish to thank the Department of Computer Engineering at Suryodaya College of Engineering & Technology, Nagpur, for providing the necessary resources and environment for this research. We are especially grateful to our guide, Prof. Pravin Balbudhe, for her invaluable mentorship and support throughout this project.

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