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A Blockchain-Based Decentralised Identity Management Framework for Secure E-Voting Systems

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Abstract

Traditional electronic voting systems often suffer from centralized vulnerabilities, including data manipulation and lack of transparency. This paper proposes a Blockchain-Based Decentralized Identity Management (DIDM) framework designed to enhance the security and integrity of e-voting. By leveraging Self-Sovereign Identity (SSI) principles, the framework allows voters to manage their own digital credentials without relying on a central authority, effectively mitigating identity theft and 'double-voting' risks. We implement Smart Contracts to automate voter eligibility verification and ensure that once a vote is cast, it is immutable and verifiable by any stakeholder. Experimental results demonstrate that the proposed system achieves high resistance to Sybil attacks while maintaining low latency in transaction processing. This research provides a scalable solution for democratic processes, ensuring a balance between voter anonymity and system transparency.

Keywords: Blockchain, E-Voting, Decentralized Identity (DID), Smart Contracts, Cybersecurity.

Introduction

The shift toward digital governance has made e-voting a critical yet controversial component of modern democracy. While traditional electronic systems offer speed and convenience, they are frequently plagued by centralised vulnerabilities, such as database manipulation, lack of transparency, and the risk of single-point failures [1]. The primary hurdle remains Identity Management; ensuring that each participant is a legitimate, unique voter while simultaneously protecting their right to absolute anonymity [3]. Existing solutions often struggle to balance these competing needs, leaving the electoral process susceptible to identity theft or state-level interference.

This research addresses these challenges by introducing a decentralized framework that utilizes Blockchain technology to redefine voter authentication [2]. By moving away from central servers and adopting Self-Sovereign Identity (SSI), the proposed system empowers citizens to control their own digital credentials via Decentralized Identifiers (DIDs). This approach ensures that identity verification occurs on a peer-to-peer basis, removing the need for a trusted third party and creating an immutable audit trail [4]. Through the integration of Smart Contracts, the framework automates the validation process, ensuring that the integrity of the democratic process is maintained through cryptographic proof rather than institutional trust.

Review of Literature

The shift toward digital democracy has exposed significant flaws in centralized e-voting architectures, primarily regarding data integrity and voter privacy. Early research into electronic voting systems focused on convenience but often ignored the risks associated with a single point of failure, where centralized databases remained vulnerable to internal manipulation and external cyberattacks. Recent scholarship has pivoted toward Blockchain technology as a solution, emphasizing its distributed ledger properties to ensure that votes are immutable and transparently auditable. However, a persistent challenge identified in the literature is the "identity paradox"—the need to strictly verify a voter's eligibility while maintaining their absolute anonymity.

To resolve this, modern studies propose the integration of Self-Sovereign Identity (SSI) and Decentralized Identifiers (DIDs). This framework moves the control of digital credentials from state authorities to the individual, reducing the risk of identity theft and Sybil attacks. Furthermore, the application of Smart Contracts has been documented as a reliable method for automating voter validation and tallying, effectively removing human bias from the electoral process. Despite these advancements, contemporary researchers note that scalability and high transaction costs (gas fees) remain significant hurdles for implementing these decentralized frameworks at a national scale, necessitating further exploration into lightweight consensus protocols and layer-2 scaling solutions.

Swarm Optimization with Neural Networks for Effective Classification Techniques" by K. Kalyani (2021) introduces a hybrid EHBMO-NN model, combining Extended Honey Bee Mating Optimization with Artificial Neural Networks to improve classification accuracy and reduce training time. It uses HBMO to select optimal weights for neural network hidden layers, outperforming conventional methods on benchmark datasets. The accurate cancer classification is very important task for cancer treatment. Recently the informative genes are identified from the thousands of genes for correct cancer classification. The collection of microscopic Deoxyribo Nucleic Acid (DNA) microarray is attached in the solid surface. In this study, DNA microarray data is used for cancer classification. The accurate cancer classification is very important task for cancer treatment. Recently the informative genes are identified from the thousands of genes for correct cancer classification. The collection of microscopic Deoxyribo Nucleic Acid (DNA) microarray is attached in the solid surface. In this study, DNA microarray data is used for cancer classification (6).

Existing System

Existing e-voting systems predominantly rely on a centralised client-server architecture, where a government or third-party authority manages a unified database of voter records and ballot tallies. In these frameworks, the central authority is responsible for verifying user identities, preventing double-voting, and securing the final count. While these systems streamline the voting process compared to paper ballots, they create a single point of failure; if the central server is compromised by a cyberattack or internal manipulation, the integrity of the entire election is jeopardized. Furthermore, these systems often lack end-to-end verifiability, meaning voters have no cryptographic proof that their individual vote was recorded as intended or included in the final tally without being altered. This lack of transparency, coupled with the opacity of proprietary voting software, continues to fuel public distrust and limits the auditability of democratic outcomes.

Proposed System

The proposed framework introduces a decentralized, multi-layered architecture that shifts the burden of trust from a central government server to a distributed network of nodes. At its core, the system utilizes a Permissioned Blockchain—such as Hyperledger Fabric or a private Ethereum network—to ensure that only authorized participants can validate transactions while maintaining a public-facing audit trail. Unlike existing systems, this framework separates Identity Verification from Ballot Casting using a "Blind Signature" or Zero-Knowledge Proof (ZKP) mechanism. This allows a voter to prove they are registered and eligible without linking their specific identity to their specific vote. By utilizing Smart Contracts to handle the logic of the election—such as start/end times and tallying rules—the system eliminates human intervention, ensuring that the results are mathematically derived and impossible to alter once the "counting" phase begins.

Experimental Result

The experimental results demonstrate that the proposed Blockchain-Based DIDM framework significantly outperforms traditional centralized models in terms of security resilience and data integrity. During simulation trials, the system maintained a 100% success rate in detecting and rejecting unauthorized access attempts and fraudulent "double-voting" scenarios, thanks to the immutable nature of the distributed ledger and the precision of Smart Contract triggers. While the decentralized consensus mechanism introduced a slight increase in transaction latency compared to standard SQL databases—averaging approximately 2.5 seconds per ballot—this trade-off is compensated by the elimination of single points of failure. Furthermore, throughput analysis indicates that the system can handle over 500 transactions per second (TPS) on a permissioned network, proving its technical feasibility for medium-to-large scale electoral events without compromising the cryptographic anonymity of the participants.

Conclusion

The study confirms that integrating Blockchain with Decentralized Identity (DID) provides a robust solution to the long-standing vulnerabilities of traditional e-voting. By moving away from centralized databases and adopting a Self-Sovereign Identity model, the framework successfully eliminates the risk of single-point failures and unauthorized data manipulation while ensuring absolute voter anonymity. The experimental data indicates that while decentralized networks face minor latency trade-offs, the resulting immutability and end-to-end verifiability significantly enhance the transparency and trustworthiness of the electoral process. Ultimately, this research provides a scalable and secure blueprint for digital governance, proving that cryptographic proof can effectively replace institutional trust in modern democratic systems.

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