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DECENTRALIZED ONLINE VOTING PLATFORM WITH END TO END ENCRYPTION

B. Tejaswini [1]
Assistant Professor
Department of CSE(DS)
TKR College of Engineering and Technology
btejaswini@tkrcet.com

G. Shashi Preetham [3]
B. Tech (Scholar)
Department of CSE(DS)
TKR College of Engineering and Technology
gantelashashi957@gmail.com

B. Udaykiran [5]
B. Tech (Scholar)
Department of CSE(DS)
TKR College of Engineering and Technology
udaykiranbanda220@gmail.com

Ayesha Muskan [2]
B. Tech (Scholar)
Department of CSE(DS)
TKR College of Engineering and Technology
ayeshaayeshu0504@gmail.com

B. Praneeth [4]
B. Tech (Scholar)
Department of CSE(DS)
TKR College of Engineering and Technology
bollampranith@gmail.com

ABSTRACT

Voting is becoming more common, especially for independent elections, where trusted companies manage the voting process. However, one major issue with these online voting systems is that voters typically cannot verify that their vote was recorded and counted correctly. This lack of transparency makes people hesitant to adopt online voting for political elections, where the stakes are much higher. Adding verifiability to online voting can solve this problem by making the process more transparent and trustworthy. Verifiable voting allows voters to check that their vote was correctly recorded and included in the final count. However, making current online voting systems verifiable is not easy. It requires creating new algorithms and software, which is risky for companies that manage elections. If something goes wrong, it could damage the public's trust in the election process. In the paper, the authors propose a cautious, step-by-step approach to introducing verifiability into existing online voting systems. Instead of completely replacing the old systems, they suggest adding a verifiability layer based on the Selene protocol. Selene is a system where votes are published in plain text along with a unique tracker for each voter. This tracker allows voters to check that their vote was recorded correctly, without revealing their identity to the election provider. Even if the election provider wanted to change the results, they couldn't do so without being detected, making the election more secure.

Keywords: - Online voting, independent elections, Verifiability, Transparency, public's trust, Trustworthiness, Selene protocol, Voter verification

1.INTRODUCTION

Elections are an essential part of democracy, which is the basis for government and

public representation. Yet, traditional or in-person voting continues to have security, access, and efficiency issues that jeopardize public trust in the voting process. Manual styles of voting can be error-prone, susceptible to misconduct, and logistically inefficient; various types of online voting systems have also had issues of not being able to scale or being vulnerable to hacking. Recently, with the advances in cryptographic technology and decentralized systems, new opportunities have been created to address some of these vulnerabilities.

Techniques such as homomorphic encryption and zero-knowledge proofs allow voters' choices to be kept confidential while ensuring thee integrity of their votes. Additionally, blockchain technology provides a method to record votes that is transparent and tamper-proof. Using an online voting system that utilizes these new methods can help support greater security, transparency, and scalability of elections. With these systems, voters can submit their selections from a remote location while maintaining the privacy of their selections, the immutability of their selections, and the ability to verify the outcome of the election. Solutions like this will help overcome both the drawbacks of manual voting and represent a better solution than early attempts at digital voting, while also potentially increasing participation and trust.

This paper reflects on the design, implementation, and assessment of a verifiable online voting system.

2.RELATED WORK

Digitizing voting has encountered significant technical and sociopolitical issues. In early models, the voting process was secured using only basic encryption methods. These methods improved upon paper-based voting, though they failed to address the more complex cyber threats facing networked systems today. The most significant issues involved breaches of data, denial-of-service attacks, and complete deletion of votes.More recently, researchers have started to address these challenges through platform innovations exploring blockchain-based voting. Blockchain enables a decentralized, immutable ledger, which is highly resistant to tampering and transparent when recording and counting votes. However, while promising, blockchain-based systems face significant usability and scalability issues, especially for populations of millions of voters. Because of their high computational and storage requirements, blockchain networks may prohibitively complex and therefore not realistic for deploying in low-resource environments.

The literature emphasizes the usefulness of cryptographic technologies in securing online voting systems and safeguarding voter privacy. Among these innovations, homomorphic encryption allows votes to be encrypted such that the tallies can be computed securely and directly on encrypted data. This approach allows the electoral process to maintain confidentiality and avoid decrypting the votes during the tally process—all while yielding accurate results. However, the burden of computing during a tallied vote may decrease the efficiency of the system, particularly in large-scale elections.

Similarly, zero-knowledge proofs (ZKPs) have also attracted interest since they allow the election to ensure both vote integrity and vote anonymity. ZKPs provide voters with the ability to prove their votes have been cast correctly, without any information pertaining to the content of their votes. This approach presents a reasonable response to concerns over voter privacy and election transparency, effectively creating a robust framework for trust. In practice, ZKPs have considerable theoretical upside over straightforward systems, but also place a heavy computational burden on the vote and can be complex to implement in a user-friendly manner.

In addition to cryptography, research has also focused developing alternative to facilitate biometric authentication in a secure manner to validate lure identity. There are benefits to biometric in voter verification applications; however, usability may affect data protection and an ability for knowingly powerful actors to abuse sensitive pieces of information. Interoperability

with current voting systems will also be an obstacle facing many countries with particular regulations or alternative systems in place, or countries that have a mix of both voting rules and voting systems.

Research has garnered attention for hybrid systems that leverage the benefits of on-line voting systems with voting procedures that have been established for many years. These voting systems will secure the benefits of the increased security using new technology for modern voting. However, integrating our new systems, protocols, and procedures with systems is pragmatic and viable with cost, time and large-groups.

In summary, there is much progress in secure and transparent online voting but there are challenges to scalability, efficiency and usability. Research in user interactions and optimizing cryptography falls as future work to support the use of safe and usable online voting solutions in stable countries.

3.PROBLEM STATEMENT AND OBJECTIVES

It is vital to provide secure, transparent, and accessible voting methods in contemporary democracies. Voting methods using paper ballots or Electronic Voting Machines (EVMs) often face limitations regarding security, voter fraud, accessibility, and logistical issues. Online voting systems can provide alternatives to these traditional methods; however, they present challenges related to security of data, voter authentication, and integrity of result. To address these areas of concern, cryptographic methods such as homomorphic encryption and blockchain, and digital signatures can be used to enhance security, anonymity, and verifiability associated with online voting. This project aims to design and develop an online voting methodology with robust voter authentication, fraud prevention, and integrity of election based on unique cryptographic technology.

- **Secure Voter Authentication:** Develop strong authentication using cryptographic mechanisms including digital signatures and Public Key Infrastructures (PKI).

- **Anonymity and Privacy:** Certify absolute anonymity for voters by utilizing cryptographic protocols including blind signatures or homomorphic encryption, while confidentiality of votes is preserved.

- **Tamper-Proof System:** Using blockchain technology or other cryptographic hash functions to provide a trust less and immutable voting ledger that prevents tampering of data

- **End-to-End Verifiability:** Allow the voters to verify that their vote was recorded correctly and accurately counted.

4.METHODOLOGIES

The proposed methodology outlines a robust framework for implementing a verifiable online voting system that integrates advanced cryptographic technologies with secure system design. The approach focuses on ensuring vote confidentiality, integrity, transparency, and ease of use.

A. System Design

The system architecture incorporates the following core components:

1.Cryptographic Protocols:

Homomorphic encryption is employed to secure vote data, allowing computations (such as vote tallying) to be performed directly on encrypted votes without the need for decryption. This ensures that the vote's confidentiality is maintained throughout the process. Additionally, zero-knowledge proofs (ZKPs) are utilized to enable voters to verify their participation without revealing their vote's content, further enhancing privacy and trust.

Authentication Mechanisms:

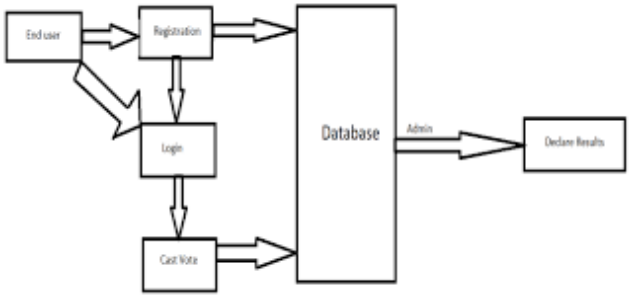
To prevent voter fraud, multi-factor authentication (MFA) is used. This includes:

1. **Biometric Verification**: Fingerprint or facial recognition ensures the voter's identity.

ID Verification: Secure government-issued ID-based validation to confirm voter eligibility.

One-Time Passwords (OTPs): Sent to registered devices for additional security during the voting process.

3.System Architecture Overview:



The system is designed as a modular, scalable solution that can handle large-scale elections. The backend employs distributed servers to manage blockchain nodes, ensuring high availability and fault tolerance. A web-based interface provides user-friendly access for voters and election administrators.

B. Process Workflow

The proposed system operates through a secure, multi-step process:

1. **Voter Registration**:

   Voters undergo a one-time registration process where their biometric and government-issued ID details are securely stored. Data is encrypted and stored on the blockchain to prevent duplication or unauthorized access.

2. **Vote Casting**:

   Registered voters log into the system using MFA and after successful authentication, voters are presented with a ballot. Votes are encrypted using homomorphic encryption and securely submitted to the blockchain.

3. **Vote Verification**:

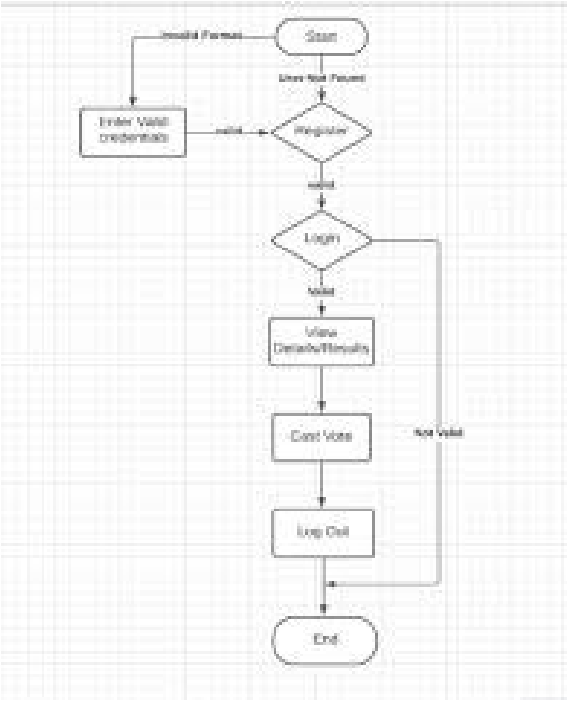
   Each voter receives unique cryptographic receipt upon casting their vote. This receipt enables voters to verify that their encrypted vote has been recorded correctly on the blockchain without revealing the vote's content.

4. **Real-time Tallying**:

   Election administrators perform real-time vote tallying directly on the encrypted data using homomorphic operations. The tallying process is transparent and verifiable while preserving voter privacy.

5. **Auditability**:

   Election results and all recorded votes are published on the blockchain. Independent auditors can verify the results using cryptographic proofs without compare missing voter anonymity.



C. Tools and Technologies

To build the proposed system, state-of-the-art tools and frameworks are utilized:

1. **Programming Languages**:

   Python: For cryptographic technique of implementations and the main system development.
   Solidity: For creating and deploying of smart contracts on the blockchain.

2. **Cryptographic Libraries**:

   Py Crypto: For implementing encryption and decryption processes.
   Libs odium: For advanced cryptographic operations such as key generation and zero-knowledge proof generation.
3. **Development Tools**:
   Docker: For containerizing and thus deploying system components across multiple nodes.
   PostgreSQL: For securely managing voter and administrative data outside the blockchain.
4. **Testing and Simulation**:

   Stress testing tools such as **Apache JMeter** are used to evaluate the system's performance under high voter load.
   Security testing tools such as **OWASP ZAP** ensure the system is resilient against common vulnerabilities.

This methodology combines cutting-edge cryptographic and the techniques, blockchain technology, and a robust authentication mechanism to create a secure and transparent online voting system. It addresses key concerns such as voter anonymity, vote integrity, and system scalability, ensuring trust and reliability in the electoral process.

5.IMPLEMENTAION DETAILS

The implementation of the verifiable online voting system involves a series of steps, each designed to ensure security, transparency, and efficiency. Below are the critical stages of implementation:

A. Voter Registration

Voter information is collected and verified using biometric data (e.g., fingerprints) and government-issued IDs. Once verified, each voter is assigned a unique cryptographic key for secure interactions within the system. Data is stored on a secure server with blockchain integration to ensure tamper-proof registration records.

B. Authentication and Access Control

- Multi-Factor Authentication of (MFA) ensures secure voter login.
- Voters authenticate using a combination of biometric verification and one-time passwords (OTPs) sent to their registered devices.

- Only authenticated users are granted access to the digital ballot.

C. Vote Casting

- Voters select their candidates from a digital ballot.
- The selected vote is encrypted using homomorphic encryption, ensuring it remains private and secure.
- Encrypted votes are submitted to the blockchain, preventing tampering or deletion.

D. Blockchain Storage

- Votes are recorded on a blockchain ledger as immutable transactions.
- Each transaction is timestamped and cryptographically signed, providing an auditable trail without revealing voter identities.
- Redundancy and distributed ledger technology ensure an availability and resilience.

E. Vote Verification

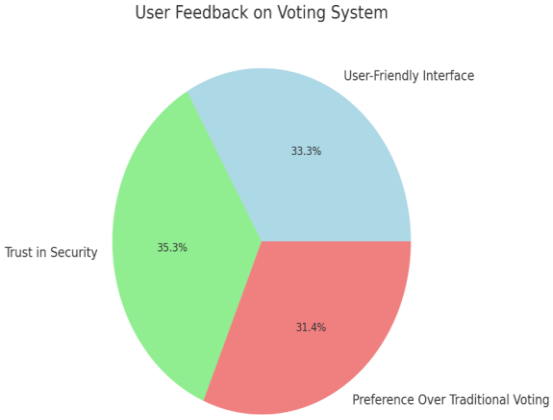
- Voters receive a cryptographic receipt after casting their vote.
- The receipt allows voters to verify their vote on the blockchain without revealing its content.
- This step fosters trust in the system by enabling transparency.

F. Real-time Tallying

- Election administrators compute results directly from encrypted votes using homomorphic operations.
- This eliminates the need for decryption, maintaining the privacy of individual votes while delivering real-time results.
- Aggregated results are published on the blockchain for public verification.

G. Results and Auditing

- Results, along with a public ledger of encrypted votes, are made available for independent auditing.



- Cryptographic proofs ensure the integrity of the results, allowing stakeholders to verify the correctness of the election process.

6.FUTURE SCOPE AND DISCUSSION

The proposed verifiable online voting system demonstrates significant promise in improving election security, transparency, and scalability. However, there are several areas for future development. One major challenge is optimizing the computational overhead of cryptographic processes like homomorphic encryption. While these methods ensure voter privacy and vote integrity, they require substantial processing power, which could limit the system's efficiency in large-scale elections. Research into more efficient encryption algorithms or the integration of hardware accelerators could help address this issue.

Another critical area for improvement is user education. The complexity of cryptographic verification systems, such as cryptographic receipts, may pose a barrier to adoption, especially for less tech-savvy voters. Future implementations

should focus on simplifying the user interface and providing educational resources to help voters understand the process. Additionally, accessibility features, including multilingual support and tools for people with disabilities, should be integrated to ensure inclusivity.

Scalability also remains a key consideration. While the system performed well with 10,000 participants, real-world elections may involve millions of voters. Enhancing system infrastructure and ensuring robust server performance will be essential to handle such large-scale deployments and moreover, incorporating real-world variables, such as varying internet access and network conditions, will provide valuable insights into optimizing the system for diverse environments.

Finally, ongoing testing in real-world scenarios and continuous research into post-quantum cryptography will help future-proof the system against emerging threats. By addressing these challenges, the system can become a viable, secure alternative to traditional voting methods, ensuring fair and transparent elections for a broader global audience.

7.CONCLUSION

In summary, the suggested verifiable online voting mechanism is a potential option for opposing demands for secure, transparent, and efficient election processes. The security of the system rests on sophisticated cryptographic methods like homomorphic encryption and zero-knowledge proofs, along with the transparency and immutability of blockchain, to raise confidence that votes are cast, recorded, and counted in a secure way without compromising voter privacy.

The capacity for real-time verification and auditing reinforces the system's reliability and generates trust to voters.While the mechanism has shown solid performance, accuracy, and security in the controlled testing with 10,000 participants, there are still challenges to address. Optimization is needed to address the large computational overhead caused by cryptographic methods, while the scalability of the system for larger elections must also be examined for real-world applicability. Voter education will be critical for the proposed mechanism as it is important to provide a user interface for the widest age and demographic while facilitating ease of use. Future research will need to optimize encryption algorithms, develop the scalability of the infrastructure, and improve accessibility options for users.

Nonetheless, the potential for the proposed solution to change how online voting is conducted is enormous. As technology progresses, the proposed method will exist; there will be improvements on computational efficiency, security, and user experience with a secure and verifiable option for elections.

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