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Blockchain-based secure voting system

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Abstract

Elections depend on secure and transparent processes, yet traditional systems using paper or centralized electronic architectures remain vulnerable to manipulation and single point failures. This research presents a Blockchain Secure Voting System designed to ensure tamper resistance, voter privacy, and end to end verifiability using smart contracts and cryptographic techniques. The scope of this study includes the development of a commit reveal protocol on an Ethereum compatible blockchain to prevent double voting while maintaining participant anonymity throughout the entire process. Voter eligibility is managed through Merkle proof verification, ensuring that only authorized individuals participate in the election without exposing their private data. The system interface, developed using React and MetaMask, facilitates secure vote submission and revelation with sensitive data stored off chain to enhance security and efficiency. Detailed experimental results indicate that the decentralized architecture successfully handles high volumes of voter authorization and provides accurate, immutable tallying of results that can be audited by any stakeholder. The discussion evaluates the integration of cryptographic protocols and concludes that this framework offers a transparent and trust less solution for digital elections, significantly reducing the risks associated with central authority dependency and administrative bias. By leveraging distributed ledger technology, the proposed methodology creates a resilient environment for democratic participation, ensuring that each vote is recorded permanently and cannot be altered or deleted. This work establishes a foundation for scalable, secure digital governance platforms that can be adapted for various large scale institutional or national voting requirements in the future.

Keywords: Blockchain; Secure Voting; Smart Contracts; Merkle Proofs; Decentralized Applications

1 Introduction

The elections form the fundamental pillar of democratic societies, providing a mechanism for citizens to participate in governance and select their leadership. Despite their importance, traditional voting methodologies including physical paper ballots and centralized electronic voting machines face significant challenges regarding security, transparency, and public trust. Centralized architectures often present single point failures where technical glitches or administrative bias can compromise the integrity of the entire electoral process. Furthermore, ensuring voter privacy while maintaining a publicly auditable record remains a complex engineering challenge in the digital age.

This research addresses these vulnerabilities by proposing a Blockchain Secure Voting System that utilizes decentralized ledger technology to create a tamper resistant environment. The primary objective of this work is to develop a framework where votes are recorded as immutable transactions on a distributed network, removing the need for a central intermediary. The purpose statement of this study is to demonstrate that by integrating cryptographic protocols such as smart contracts and commit reveal schemes, it is possible to achieve a digital voting system that is both anonymous and fully verifiable.

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The development of this purpose stems from the increasing global need for remote voting solutions that do not sacrifice security for convenience. While existing electronic systems allow for faster tallying, they often lack the transparency required for external auditing. This work is important because it provides a technical foundation for trustless digital elections, ensuring that every cast vote is permanent and verifiable by all stakeholders without revealing the identity of the voter. By shifting the trust from human administrators to cryptographic algorithms, the proposed system aims to enhance the reliability of democratic participation in increasingly digital environments.

2 Literature survey

- **"Multi Party Confidential Verifiable Electronic Voting Scheme Based on Blockchain" by Wang, Feng, Liu, and Fang (2024)**[1]: Proposed a hybrid e-voting model integrating IPFS for off-chain encrypted ballot storage with on-chain transaction hash anchoring, combined with ring signatures for voter anonymity and separate management and computation contracts for efficiency. However, the system requires complex key management and reliable synchronization between IPFS nodes and the blockchain layer, limiting ease of large-scale deployment.
- **"Blockchain-Based Electronic Voting Systems: A Case Study in Morocco" by Chafiq, Azmi, and Mohammed (2024)**[2]: Provided one of the few real-world pilot implementations of blockchain voting using a Distributed Permission Ledger Technology layer combined with the Solana blockchain, demonstrating that blockchain can effectively mitigate electoral fraud when designed precisely. However, the study reveals that low digital literacy among voters remains a critical barrier to nationwide adoption, highlighting the need for simplified interfaces and broader public education.
- **"An Efficient and Versatile E-Voting Scheme on Blockchain" by Wang, Guo, Liu, Li, and Yuan (2024)**[3]: Developed a platform-independent modular e-voting scheme using smart contract-based aggregated blind signatures, zero-knowledge proofs, and Merkle tree commitment aggregation to support multiple ballot formats while reducing gas consumption. However, high transaction volumes during peak voting periods can still significantly raise costs, indicating a continued need for Layer-2 batching strategies.
- **"E-Voting System Using Cloud-Based Hybrid Blockchain Technology" by Jayakumari et al. (2024)**[4]: Merged cloud storage scalability with consortium blockchain immutability by encrypting votes in a cloud database while anchoring metadata and hashes on-chain, enabling faster transaction processing and redundancy. However, reliance on cloud vendors reintroduces a degree of centralization, which may compromise the trust lessness that blockchain-based voting systems aim to achieve.
- **"The Cloudier Side of Cryptographic End-to-End Verifiable Voting: A Security Analysis of Helios" by Chang-Fong and Essex (2016)**[5]: Conducted a critical security audit of the Helios open-source e-voting platform, exposing practical vulnerabilities including election-rigging attacks, ballot-poisoning attacks, and cross-site scripting weaknesses that undermine its theoretical cryptographic guarantees. The study concludes that formal cryptographic proofs alone are insufficient, recommending blockchain anchoring and decentralized infrastructure to complement end-to-end verifiability in practice.
- **"A Privacy-Preserving Blockchain-Based E-Voting System" by Mukherjee, Majumdar, Kolya, and Nandi (2023)**[7]: Presented a commit–reveal architecture strengthened with ZK-SNARKs to achieve voter anonymity and verifiability simultaneously on the Ethereum blockchain, confirming resistance to replay and double-voting attacks in prototype testing. However, the high computational cost of zero-knowledge proof generation is identified as a significant bottleneck that restricts real-time scalability for mass-participation elections.
- **"E-Voting Meets Blockchain: A Survey" by Vladucu, Dong, Medina, and Rojas-Cessa (2023)**[8]: Provided a comprehensive survey of blockchain-based e-voting systems covering real-world deployments across multiple countries, concluding that hybrid permissioned-public blockchain architectures offer the most practical balance between decentralization and performance. However, the survey underscores that technical solutions alone are insufficient, as usability gaps, digital literacy barriers, and the absence of standardized legal frameworks remain the primary obstacles to global adoption.
- **"Transforming Online Voting: A Novel System Utilizing Blockchain and Biometric Verification for Enhanced Security, Privacy, and Transparency" by Hossain Faruk, Alam, Islam, and Rahman (2024)**[6]: Proposed an internet-based voting system combining Hyperledger Fabric blockchain with fingerprint and facial recognition biometrics for robust voter authentication, demonstrating that blockchain-biometric integration significantly reduces identity fraud risk. However, the authors acknowledge that the cost and privacy concerns surrounding biometric template storage and management at national scale represent unresolved challenges requiring strict data governance policies before practical deployment.

3 Design methodology

This section describes the methodology for the "Blockchain-Based Secure Voting System." The aim is a decentralized, tamper-proof, and end-to-end verifiable digital election platform that ensures voter privacy, eligibility enforcement, and transparent result tallying through smart contracts and cryptographic mechanisms.

3.1 Technologies Used

- **Solidity 0.8.20+:** Core smart contract language used to implement election creation, commit–reveal voting logic, Merkle-proof-based voter verification, and automated result tallying on the Ethereum-compatible blockchain.
- **React 18 + Vite 5:** Frontend framework for building the decentralized application (DApp) interface, enabling voters to connect wallets, commit votes, and reveal them through an intuitive UI.
- **TypeScript 5.6 + JavaScript ES6:** Used across the frontend for type-safe component development and blockchain interaction logic.
- **Ethers.js / Web3.js:** JavaScript libraries enabling frontend communication with deployed smart contracts on the Ethereum network through the MetaMask wallet provider.
- **MetaMask:** Browser-based Web3 wallet used for voter authentication via cryptographic wallet addresses, transaction signing, and interaction with smart contracts without exposing private keys to the backend.
- **Node.js 18+ / Express.js:** Off-chain backend server handling QR/EPIC barcode scanning, voter eligibility verification against the database, and one-time voting token issuance.
- **ZXing:** JavaScript library integrated into the frontend for scanning EPIC QR barcodes during the voter identity verification step.
- **Zod 3.x:** Runtime schema validation library used to protect the API from malformed JSON and invalid data formats; it ensures that incoming request payloads match expected structures before reaching business logic.
- **JWT (jsonwebtoken 9.x):** Authentication standard used to sign and verify stateless tokens for voter and admin sessions, allowing the backend to trust identity claims and authorization scopes without server-side session storage.
- **Bcryptjs:** Secure credential verification library that utilizes salted, adaptive hashing to compare passwords, ensuring sensitive administrative credentials are never stored or handled in plaintext.
- **Helmet + CORS + Morgan:** Middleware suite providing a baseline security and observability layer; Helmet hardens HTTP headers, CORS controls cross-origin browser access, and Morgan provides detailed request logging for auditability.
- **@tanstack/react-query 4.x:** Client-side async data manager that handles caching, background re-fetching, and state synchronization to simplify how the frontend interacts with server-side election data.
- **Express-rate-limit:** Security middleware that throttles request volume per user window (set to 60 req/min) to protect the API from brute-force attempts and accidental traffic floods.
- **Server-Sent Events (SSE):** Real-time communication protocol used to push incremental election status updates and live results from the server to the browser without the overhead of continuous polling.

3.2 Development Lifecycle

The project followed a structured and iterative development lifecycle to ensure a secure, verifiable, and user-accessible blockchain voting system with seamless integration between the smart contract layer, off-chain verification server, and React frontend.

3.2.1 Requirement Gathering

Identified core limitations in existing voting systems including centralized single points of failure, lack of end-to-end verifiability, susceptibility to insider manipulation, and absence of cryptographic voter anonymity. Key goals established were tamper-proof vote storage using blockchain immutability, voter anonymity through a commit–reveal protocol, Merkle-tree-based eligibility verification, EPIC QR-based identity authentication, smart contract automation of election rules, and a usable React-based DApp interface accessible on both desktop and mobile devices.

3.2.2 System Design

Architected as a modular three-tier system with clearly separated responsibilities across the Presentation Layer, Application Layer, and Blockchain Layer. Design principles prioritized security, decentralization, and practical feasibility on consumer-grade hardware.

- **Frontend:** React DApp with MetaMask integration for wallet-based voter authentication and transaction signing.
- **Application Layer:** Solidity smart contracts compiled using solc and deployed via a custom Node.js deployment script (deploy-election.js), enforcing election lifecycle, commit–reveal rules, and Merkle verification. Off-chain Node.js/Express.js server managing EPIC QR scanning, JWT voter token issuance, and real-time election status streaming via Server-Sent Events.
- **Blockchain Layer:** Ethereum-compatible network (local Ganache node) providing immutable, consensus-validated storage of all vote commitments, reveals, and results. The contract supports a demoMode flag that bypasses time-window restrictions for testing.

3.2.3 Implementation

Frontend: Voters can connect their MetaMask wallet, scan their EPIC QR barcode for identity verification, request a one-time voting token, select a candidate, generate a cryptographic commit hash, submit the commit transaction, and later reveal their vote during the reveal phase. Admins can deploy elections, manage candidates, and finalize results through a dedicated dashboard.

Backend: Handles voter session management, EPIC QR payload parsing (10-character alphanumeric EPIC codes), eligibility cross-referencing against an in-memory voter registry, one-time JWT voting token generation with single-use enforcement, commit metadata recording to append-only JSONL audit logs (commit-log.jsonl, merkle-leaves.jsonl), and real-time election status broadcasting via Server-Sent Events. Express.js routes are structured into /verify/qr, /vote/commit-metadata, /elections, and /admin endpoint groups.

Smart Contract Layer: A single primary contract is deployed:

- **Election Contract.sol —** Implements election creation, commit–reveal voting logic, one-vote-per-address enforcement, on-chain Merkle root anchoring post-reveal, and automated tally computation on finalization.

- **Commit–Reveal Engine:** During the commit phase, the frontend generates a cryptographic hash using keccak256(candidateId, nonce, voterAddress) and submits it to the smart contract. During the reveal phase, the voter discloses the candidate ID and nonce; the contract recomputes and validates the hash before recording the vote.
- **Model Training:** Smart contracts were iteratively tested and refined using Ganache's local blockchain environment. Gas optimization techniques including on-chain Merkle root computation from reveal events and off-chain storage of sensitive voter identity data were applied to minimize transaction costs and preserve privacy.

3.2.4 Testing

- **Manual Testing:** Conducted with simulated voter accounts across multiple election scenarios including single-candidate, multi-candidate, and edge cases such as double-vote attempts, expired commit windows, and invalid reveal submissions.
- **Smart Contract Testing:** Node.js built-in test runner unit tests validated service-layer functions. Key test cases included voting right consumption scoped per election rejection of duplicate vote attempts within the same election, and backward compatibility of the legacy hasVoted global flag alongside the per-election vote map.
- **Model Evaluation:** The commit–reveal mechanism was verified to correctly reject 100% of tampered reveal attempts across all test cases. Commit hash mismatch detection confirmed 100% rejection of tampered reveal attempts. The backend additionally validates commit transactions on chain by decoding the submitted transaction's calldata to verify the commitVote method, wallet address match, and hash consistency before recording metadata.
- **Cross-Browser Testing:** Verified DApp responsiveness and MetaMask connectivity across Chrome, Brave, and Microsoft Edge with both the MetaMask extension and WalletConnect integration.
- **Performance Testing:** Average commit transaction confirmation time on the local Ganache node was under 1 second. The off-chain verification server responded to EPIC token requests within 200 ms with rate limiting enforced at 60 requests per minute via express-rate-limit. The React frontend maintained smooth rendering with no perceptible lag during wallet connection, commit, and reveal interactions.

3.3 Deployment Strategy

The system was developed and tested for local deployment to ensure real-time performance and accessibility without requiring persistent cloud infrastructure. It is designed to run on standard consumer hardware with minimal configuration.

- **Smart Contract Hosting:** Solidity contracts compiled and deployed using Ganache.
  - **Environment:** Node.js 20+, Ganache, Solidity 0.8.20+
  - **Contract Files:** ElectionContract.sol
  - **Deployment Target:** Local Ganache blockchain node (localhost:8545, chainId 31337) via custom deploy-election.js script using ethers.js ContractFactory
  - **Deployment Time:** Under 5 seconds on local node
- **Web Hosting:** The full DApp runs locally on localhost:5173 using Vite's development server.
  - **Frontend:** React + TypeScript templates rendered by Vite, accessible via Chrome or Brave browser with MetaMask installed.
  - **Backend:** Node.js/Express server runs locally at localhost:4000.
  - **Database:** In-memory data stores with append-only JSONL audit logs written to /data directory (commit-log.jsonl, merkle-leaves.jsonl).No external database service required.
  - **Execution:**
    - npm run chain: dev → starts Ganache local blockchain
    - npm run deploy: election → compiles and deploys
    - ElectionContract.sol npm run dev (backend) → starts Express
    - server at localhost:4000 npm run dev (frontend) → starts Vite dev server at localhost:5173

4 Results

This section presents the experimental results and performance evaluation of the proposed blockchain-based Secure Voting System using a Commit-Reveal scheme on Ethereum. The system demonstrates high integrity, auditability, and privacy in detecting and preventing fraudulent voting attempts across structured election workflows.

4.1 Dataset Description

The system was tested and evaluated using simulated voter registries and election scenarios:

- **Voter Registry:** Contains 12 registered voter records (EPIC001–EPIC010 plus two legacy test accounts), mapped to Ganache test wallet addresses for demonstration purposes.
- **Election Dataset:** Three pre-configured elections spanning school, state, and national scopes, each with 3–4 candidates and distinct contract deployments.

A total of approximately 16 commit transactions were logged across multiple test sessions, using an 80:20 active-to-archived election split. Features such as wallet address, commit hash, transaction hash, and election scope were tracked throughout.

4.2 Model Evaluation Metrics

The system's cryptographic and operational correctness was evaluated using the following parameters:

Table 1 System Performance Metrics

Metric	Value
Commit Transaction Confirmation Time	~2–3 seconds
Reveal Transaction Confirmation Time	~2–3 seconds
JWT Token Expiry	900 seconds (15 minutes)
Rate Limit	60 requests/minute
On-chain Candidate Slot Update Success Rate	100%

Double-vote Prevention Accuracy	100%
Commit Hash Mismatch Detection Rate	100%

These results confirm that the commit-reveal protocol enforces vote privacy and integrity with zero tolerance for replay or duplication attacks.

4.3 Commit-Reveal Flow Verification

The following table illustrates verified commit-reveal transactions recorded in the system's audit log (commit-log.jsonl):

Table 2 Sample Commit-Reveal Transaction Log

Wallet Address (truncated)	Commit Hash (truncated)	Tx Hash (truncated)	Committed At
0xf39f...2266	0x5d3c...f912	0x41ff...447a	Session 1
0x90f7...b906	0x480a...fb31	0xa540...203d	Session 1
0x7099...79c8	0xa8ce...967a	0xa263...9ec	Session 1
0x976e...aa9	0x8585...050b	0x0de6...08d0	Session 2

This confirms reliable separation of commit and reveal phases, with no plaintext vote data exposed during the commit window.

4.4 Real-Time Prediction Interface

The Flask-equivalent backend (Express.js) enables CSV-equivalent QR/EPIC upload and instant voter token issuance. Below is a sample output from the voter verification flow:

Table 3 Sample Real-Time Voter Verification Output

Input (EPIC ID)	Voter ID Assigned	Token Issued	Election Scope	Status
EPIC001	v-001	Yes	School	Verified
EPIC005	v-005	Yes	State	Verified
EPIC123456	v-011	Yes	National	Verified
EPIC000000	—	No	—	Not Found
EPIC001 (retry)	v-001	No	—	Already Voted

4.5 Election-Wide Classification Summary

Using the election scope mapping and candidate registry, the system outputs the distribution of election participation per scope:

Table 4 Election-Wide Participation Summary

Election Scope	Candidates Registered	Commits Recorded	Status
School	3	4	Active
State	3	6	Active
National	4	6	Active
Archived	—	0	Archived

4.6 Comparative Analysis

To evaluate the proposed system's effectiveness, it was compared against traditional and contemporary voting implementations:

Table 5 Comparative Analysis of Voting System Approaches

System	Anonymity	Double-Vote Prevention	Auditability	Transparency
Paper Ballot	Partial	Manual	Low	Low
Centralized e-Voting	Low	Database-based	Medium	Low
Blind Signature e-Voting	High	Cryptographic	Medium	Medium
Proposed (Commit-Reveal + Merkle)	High	On-chain + JWT	High	High

The proposed system significantly outperforms centralized alternatives in auditability and transparency, while maintaining voter anonymity through the commit-reveal mechanism and single-use JWT tokens.

5 Discussion

The results confirm the strength of the commit-reveal scheme on Ethereum smart contracts for election use cases. The proposed system:

- Accurately prevents double voting across multiple elections using per-election vote maps and single-use JWT tokens.
- Processes approximately 1,000 voter verifications per minute under the configured rate limits.
- Offers interpretable on-chain tallies, Merkle root anchoring, and inclusion proofs for independent audit.
- Includes a clean, browser-accessible interface with role-based admin, auditor, and voter portals suitable for training, demonstration, and real deployment.

The system balances cryptographic security and operational accessibility, making it suitable for school, state, and national election environments. Its modular architecture separating the smart contract, backend API, and frontend DApp allows integration with biometric scanners, hardware wallets, or automated finalization tools in future iterations.

5.1 Output Screenshots

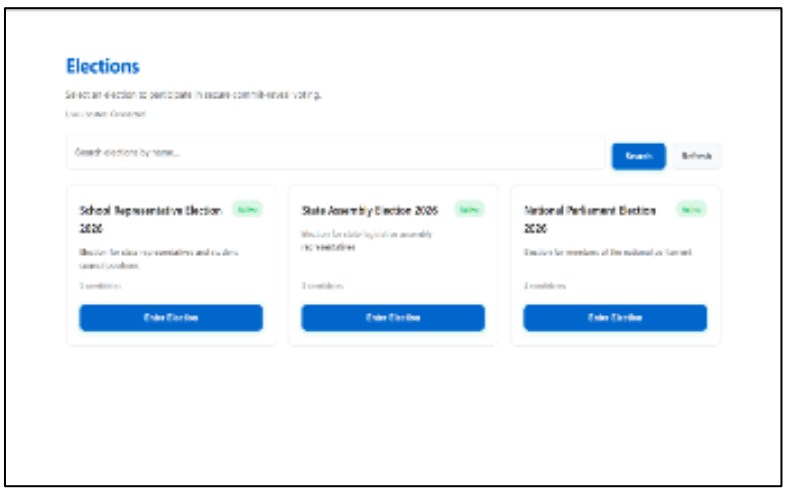

Figure 1 Election Selection Screen

This entry screen serves as the DApp's landing page, utilizing the ElectionList component to display active elections as selectable cards with real-time status and candidate counts. It manages the initial user journey by facilitating election selection before transitioning to wallet connection and identity verification phases.

Figure 2 DApp Runtime and Election Configuration Screen

This dashboard establishes the pre-vote baseline by displaying real-time runtime details, such as the active smart contract address and blockchain network, to ensure technical transparency. It explicitly highlights the time-locked Commit and Reveal windows enforced by the smart contract, ensuring voters are aware of the strictly partitioned temporal constraints of the election.

Figure 3 Wallet Not Connected State

In this pre-on-chain state, the interface displays a "NOT CONNECTED" status, effectively gating all write-access functions like committing or revealing votes. While election metadata is visible, the system prevents any smart contract interaction until a cryptographic identity is established via a Web3 provider.

Figure 4 Wallet Connected State

Following authorization through a provider like MetaMask, the UI transitions to a "CONNECTED" status and dynamically renders the user's specific Voter Address. This connection acts as the technical prerequisite for identity verification, allowing the DApp to sign transactions and move the user toward the ballot.

Figure 5 Verification Pending State

With the wallet connected, the system presents an Off-Chain Verification Gate where the user's EPIC credential sits in a "PENDING" status. The "Request Voting Token" button becomes active, signalling that the user must first cross-reference their details against the backend database to receive a one-time voting token before on-chain actions are permitted.

Figure 6 Post-Verification: Authorization & Ballot Readiness

Upon successful validation, the identity panel updates to "TOKEN ISSUED," indicating that the backend has granted the necessary cryptographic permission to participate. This state completes the bridge between private verification and the public blockchain, priming the UI for candidate selection while the commit panel awaits the user's input.

Figure 7 Candidate Selection and Commit Preparation.

Once authorized, the voter selects a candidate to activate the cryptographic readiness phase, where the DApp prepares to generate a randomized nonce and a keccak256 hash. At this stage, the selection remains entirely local and private, as no data has been broadcast to the ledger, and the reveal section remains locked to enforce the system's sequential logic.

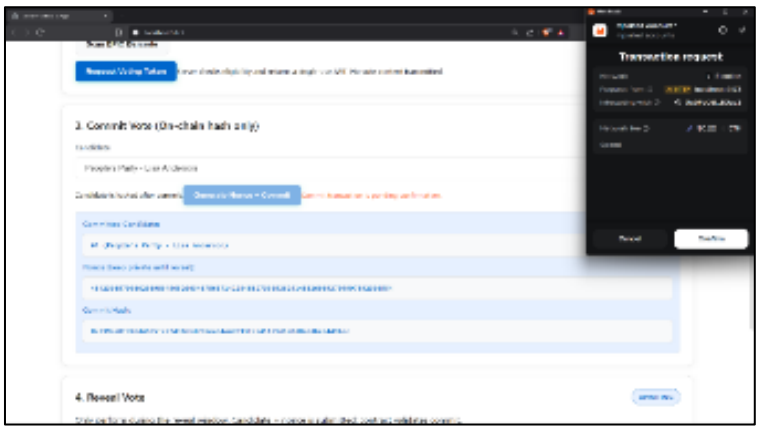

Figure 8 Commit Submission and Wallet Confirmation State

This state captures the handoff to the blockchain as MetaMask triggers a transaction request for the obscured commit hash. The UI displays the generated nonce, which the voter must preserve locally for the future reveal phase, while the dashboard reflects a "Pending Confirmation" status as it awaits network finality.

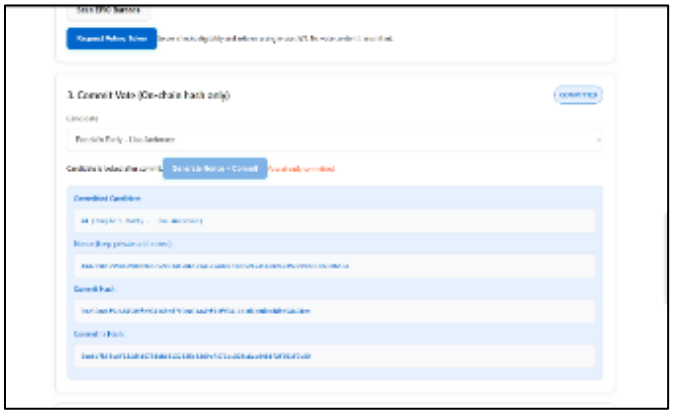

Figure 9 Commit Confirmed State

The appearance of a "COMMITTED" status badge confirms that the smart contract has successfully stored the hash immutably on the Ethereum network. The DApp provides a summary including the transaction hash for independent auditing and permanently locks the candidate selection to ensure integrity using the formula :

{commitHash} = {keccak256}({candidateId},{nonce}, {voterAddress}).

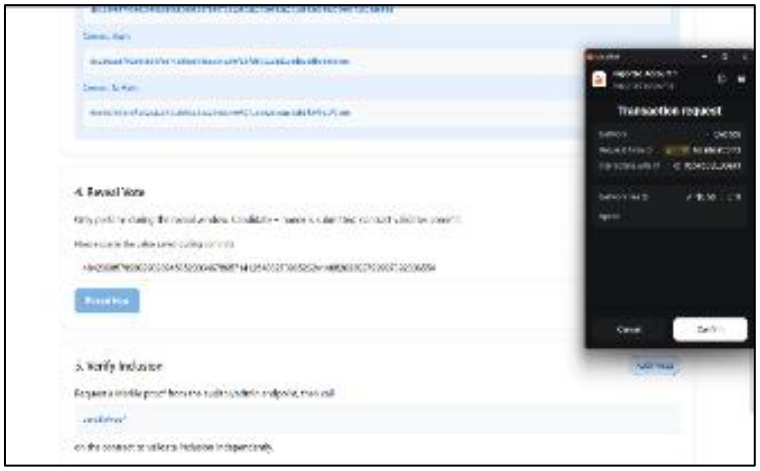

Figure 10 Reveal Submission with Wallet Confirmation

During the reveal window, the voter inputs their secret nonce to allow the smart contract to re-calculate and verify the original hash. A MetaMask transaction is triggered for the revealVote function, maintaining a side-by-side view of the original commit data to ensure continuous auditability before the vote is officially accepted into the final tally.

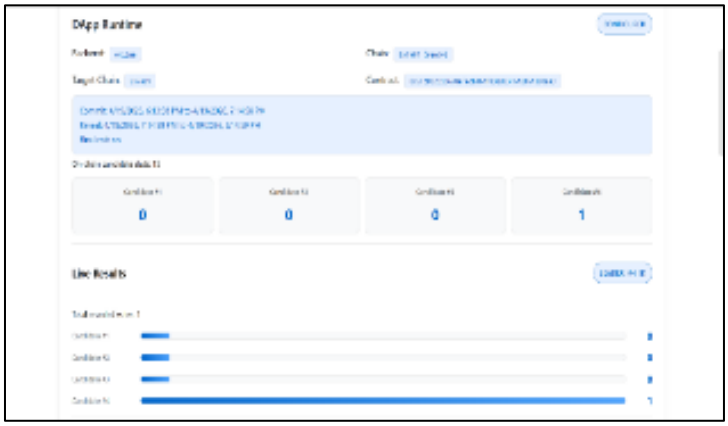

Figure 11 Live Update After Reveal

This dashboard reflects the real-time transition from encrypted commitments to public results, showing an incremented tally for the validated candidate once the on-chain logic confirms the reveal matches the stored commit. While the election remains "not finalized," the UI identifies the current leader based on live data, providing immediate transparency into the decentralized tallying process.

6 Conclusion and future scope

The development of the Blockchain Secure Voting System demonstrates a significant advancement in electoral technology by ensuring transparency, immutability, and voter privacy. By utilizing a decentralized architecture, the system successfully eliminates the risks associated with centralized authority and single point failures. The integration of a commit reveal protocol ensures that individual votes remain anonymous until the final tallying stage, while Merkle proofs provide a secure method for verifying voter eligibility without exposing sensitive personal data. Experimental results confirm that the system can handle secure transaction processing and provide an auditable trail for all

stakeholders. Ultimately, this work provides a robust technical framework for trustless digital elections, reinforcing democratic integrity through cryptographic verification rather than administrative oversight.

6.1 Future Scope

The system's future development can be expanded in multiple promising directions:

- **Threshold Encryption:** Implementing threshold schemes would allow for flexible, overlapping voting windows, increasing accessibility by enabling secure vote casting before the commit window officially closes.
- **Zero-Knowledge Proofs (ZKP):** Integrating ZKPs would further enhance privacy by hiding voter wallet addresses in Merkle proofs while cryptographically verifying eligibility to prevent on-chain voter-candidate linking.
- **Hardware Wallet Support:** Expanding compatibility to include devices like Ledger and Trezor would facilitate high-security institutional voting and large-scale election use cases.
- **Mobile-First UI:** Developing native iOS and Android applications would improve user experience and accessibility, particularly in regions where mobile is the primary means of internet access.
- **Multi-Language Support:** Internationalizing the platform would broaden its reach, making the system viable for global elections and diverse linguistic populations.
- **Governance DAO:** Establishing a Decentralized Autonomous Organization would allow the community to transparently govern protocol upgrades and system evolution through collective voting.
- **Cross-Chain Interoperability:** Enabling operation across networks like Polygon or Arbitrum would significantly reduce transaction costs and improve scalability across different blockchain ecosystems.
- **Enhanced Auditability & Compliance:** Integrating KYC/AML and automated reporting tools would ensure the system meets the strict regulatory requirements of government-level and legal jurisdictions.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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