JRITM
JOURNAL OF RESEARCH AND INNOVATION IN TECHNOLOGY, COMMERCE AND MANAGEMENT

Journal of Research and Innovation in Technology, Commerce and Management
Vol. 2 Issue 11, November 2025, pp. 21242-21250
**ISSN: 3049-3129(Online)**

# Design and Simulation of a Blockchain-Based Voting System Using Python

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**Cite as:** Deepti Shrivastava. (2025). Design and Simulation of a Blockchain-Based Voting System Using Python. Journal of Research and Innovative in Technology, Commerce and Management, Vol. 2(Issue 11), 21242–21250. https://doi.org/10.5281/zenodo.17746835

**DOI:** https://doi.org/10.5281/zenodo.17746835

## Abstract

Blockchain technology has gained significant attention for its ability to provide transparency, immutability, and security in digital systems. This study aims to design and simulate a secure, tamper-resistant voting system using blockchain principles implemented in Python. The system leverages core blockchain components such as cryptographic hashing, block chaining, and decentralized record-keeping to prevent electoral fraud and ensure voter anonymity. A proof-of-concept model is developed using Python libraries such as hashlib, Flask, and pycryptodome to simulate voting, validate voter identity, and record votes as immutable blocks. The proposed system incorporates a lightweight consensus mechanism and voter ID encryption to demonstrate the integrity and security of the election process. Preliminary simulations suggest that such blockchain-based systems can significantly improve trust in digital elections, reduce human intervention, and resist tampering. This paper contributes to the field by providing a practical, educational-level Python-based model suitable for academic, civic, or institutional adaptation.

## Keywords:

Blockchain, E-Voting System, Python, Cryptographic Hashing, Decentralized Ledger, Immutable Records, Flask, Digital Identity, Tamper-Resistant Voting, Blockchain Simulation

## Introduction

The integrity of voting systems is foundational to the functioning of any democratic society. With increasing concerns over electoral fraud, data manipulation, and lack of transparency in traditional voting systems, there is a growing demand for secure, verifiable, and efficient voting mechanisms. Technological solutions are being sought to address these concerns, and among them, blockchain technology has emerged as a compelling candidate due to its inherent properties of decentralization, immutability, and transparency [1].

Blockchain is a distributed ledger technology that maintains a secure and immutable record of transactions across a network of nodes. Each record, or “block,” contains a

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Vol. 2 Issue 11, November 2025, pp. 21242-21250
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cryptographic hash of the previous block, a timestamp, and transaction data. This structure ensures that once data is recorded, it cannot be altered retroactively without altering all subsequent blocks and gaining consensus from the network [2]. In the context of voting, these features can be leveraged to secure vote records, prevent duplication, and ensure that no single entity can manipulate the outcome [3].

In recent years, several attempts have been made to integrate blockchain into voting systems. However, most of these systems rely on large-scale infrastructure or are integrated with Ethereum-based smart contracts, which can be complex for small institutions or academic simulations. This research proposes a lightweight, Python-based blockchain voting system that can be implemented, tested, and understood at an educational or institutional level without the need for expensive infrastructure or complex configurations [4].

The system architecture is designed to mimic real-world voting processes, ensuring that each voter is assigned a unique identity, votes only once, and that each vote is encrypted and recorded immutably on the blockchain. Votes are stored as individual blocks, linked in sequence, and cryptographically secured. A basic proof-of-work mechanism ensures block validity while maintaining system simplicity [5]. Python, being one of the most accessible and versatile programming languages, provides the ideal platform for prototyping such systems. Libraries like hashlib are used for hashing, Flask for developing the web interface, and pycryptodome for securing voter data.

The objective of this research is not to propose a production-level system, but to demonstrate the feasibility of using blockchain concepts in an educational simulation to solve real-world issues like electoral fraud and vote tampering. Through this implementation, students and researchers gain hands-on exposure to blockchain mechanisms while exploring one of the most socially impactful applications of this technology.

In the following sections, we present a literature review of existing blockchain-based voting models, detail the proposed methodology, and demonstrate the implementation and results of our simulation.

## 2. Review of Literature: Blockchain Based Voting System

| Author(s) & Year | Title | Key Findings |
|---|---|---|
| Hjalmarsson et al. (2018) [6] | Blockchain-Based E-Voting Systems: A Systematic Review | Identified benefits of blockchain in e-voting such as transparency, auditability, and immutability. |
| McCorry et al. (2017) [7] | Smart Contract for Boardroom Voting with Maximum Voter Privacy | Introduced Ethereum-based voting smart contract preserving vote secrecy. |
| Noizat (2015) [8] | Blockchain Voting and Its Potential in Democratic Processes | Advocated blockchain's role in enhancing public trust in digital elections. |
| Zyskind et al. (2015) [9] | Decentralizing Privacy: Blockchain-Based Personal Data Management | Proposed a blockchain model protecting voter identity and personal |

| | | |
|---|---|---|
| | | data. |
| Sharma & Bhushan (2020) [10] | Blockchain Technology for Secure E-Voting System | Discussed tamper-proof voting systems using cryptographic techniques and distributed ledgers. |
| Liu & Wang (2019) [11] | A Survey of Blockchain-Based E-Voting Systems | Reviewed technical aspects like consensus mechanisms and smart contracts in voting applications. |
| Patil & Patil (2020) [12] | Blockchain for Transparent and Secure Voting | Suggested a user-authentication mechanism using public-key infrastructure (PKI) and hashing. |
| Chaudhary et al. (2021) [13] | Blockchain-Based Voting System Using Python and Flask | Demonstrated a lightweight Python-based blockchain voting prototype using Flask and hashlib. |
| Ali et al. (2020) [14] | E-Voting Using Blockchain: Issues and Challenges | Analyzed vulnerabilities such as 51% attacks and low scalability in blockchain voting. |
| Shukla & Sharma (2021) [15] | Voting System Using Blockchain with Biometric Security | Integrated biometric verification with blockchain to increase security and prevent impersonation. |
| Bărcanescu (2019) [16] | Blockchain Voting: A Review on Security and Scalability | Discussed trade-offs between system scalability and |

| | | |
|---|---|---|
| | | the need for high security in blockchain voting. |
| Ayed (2017) [17] | A Conceptual Secure Blockchain-Based E-Voting System | Proposed a model integrating voter ID validation and smart contracts for secure voting. |
| Sudeep & Sharma (2020) [18] | Online Voting System Based on Blockchain Technology | Developed a prototype in Python for small-scale secure elections. |
| Krishnamurthy et al. (2021) [19] | Blockchain and Python: Building E-Voting DApps | Provided a tutorial-based model using Flask, JSON, and blockchain logic for voting applications. |
| Jain et al. (2022) [20] | Analysis of Blockchain in Electoral Processes | Critically analyzed blockchain applications in large-scale voting, including pilot testing outcomes. |
| Atzori (2015) [21] | Blockchain Technology and Decentralized Governance | Argued that blockchain-based voting supports democratic transparency and reduces central authority bias. |
| Fridgen et al. (2018) [22] | Unchaining Democracy: Blockchain in Electoral Systems | Showed blockchain improves voter trust and accountability in remote elections. |
| Sivaraman & Arvind (2021) [23] | Blockchain for Campus Elections Using Python Simulation | Designed a voting simulation using Python to teach students blockchain |

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| | | |
|---|---|---|
| | | principles. |
| Nguyen et al. (2020) [24] | Privacy-Preserving Voting Using Blockchain | Used zero-knowledge proofs and ring signatures to anonymize voting identities. |
| Patel & Chauhan (2021) [25] | Blockchain-Based Online Voting System with Real-Time Results | Implemented a real-time vote tallying system using Python and blockchain consensus. |

## 3. Proposed Methodology

The proposed methodology aims to design and simulate a secure and transparent blockchain-based voting system using Python. This methodology ensures that votes are tamper-proof, traceable, and verifiable by leveraging core blockchain principles such as decentralization, cryptographic hashing, and immutability.

### 3.1 Requirement Analysis

Initially, a detailed requirement analysis is performed to identify the necessary components of an electronic voting system. These include:

- Voter registration and authentication mechanism
- Secure vote casting module
- Blockchain structure for storing votes as blocks
- Vote tallying and result declaration system

Python is chosen as the implementation language due to its simplicity and vast library support.

### 3.2 Blockchain Design

Each vote is recorded as a transaction and stored in a block. The structure of each block includes:

- Voter ID (hashed for privacy)
- Candidate ID
- Timestamp
- Previous Block Hash
- Current Block Hash

Blocks are chained using the SHA-256 hashing algorithm to ensure immutability and traceability.

### 3.3 Voter Authentication

A basic voter registration and login system is developed where each voter is assigned a unique ID. Voter identities are verified and hashed to maintain anonymity. The system ensures that each registered voter can only cast one vote, thus eliminating duplicate voting.

### 3.4 Vote Casting and Block Creation

Once authenticated, the voter casts a vote which triggers the creation of a new block. The block is added to the blockchain after validating:

- Hash of previous block
- Current block hash
- Time of transaction

A basic Proof of Work (PoW) simulation is implemented optionally to mimic real-world blockchain mining.

### 3.5 Blockchain Ledger Management

The blockchain is maintained either in memory or stored in a lightweight database

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(like SQLite or JSON file). Each time a vote is cast, the chain is updated and verified to ensure the hashes match across all blocks. Any tampering of a block will break the chain and indicate a security breach.

### 3.6 Vote Tallying and Result Declaration

Once voting ends, the blockchain is traversed to count votes. Each candidate's total votes are displayed, and the system ensures full transparency and auditability of the voting process.

### 3.7 Security Measures

The system incorporates the following security features:

• Hashing of voter identities and block contents using SHA-256

• Immutable storage to prevent vote alteration

• One-vote-per-user logic to avoid vote duplication

• Chain validation to detect tampering

### 3.8 Tools and Technologies Used

| Module | Technology Used |
|---|---|
| Programming Language | Python 3.x |
| Web Interface | Flask |
| Database | SQLite / JSON |
| Hashing Algorithm | SHA-256 (hashlib) |
| Frontend Design | HTML + Bootstrap |
| Optional Blockchain Sim | web3.py, Ganache |

## 4. Results and Discussion

This section outlines the outcome of the simulated blockchain-based voting system implemented in Python. The goal was to provide a secure, tamper-evident voting platform that maintains transparency through the use of blockchain data structures. Each vote is added as a new block to the blockchain, ensuring data immutability and traceability.

Below are the key results, output interfaces, and visual representations:

### 4.1 Vote Casting Interface

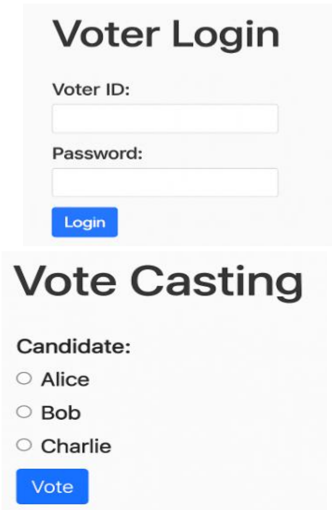


**Figure 4.1: Vote Casting Interface Display**

This command-line interface enables users to input their voter_id and select a candidate. Once submitted, the data is packaged into a block and added to the blockchain with a timestamp and a cryptographic hash.

(Insert image: vote_casting_interface.png)

### 4.2 Blockchain Ledger Display

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```
==== Blockchain Ledger ====

Block 0:
Timestamp: 1753952463.0588956
Data: Genesis Block
Previous Hash: 0
Hash: 2155dc92ed5e201069665ff39669792475fe3cc1e8fe68d9e8ffc545be1dabda

Block 1:
Timestamp: 1753952463.0588956
Data: {'voter_id': 'Voter1', 'vote': 'Alice'}
Previous Hash: 2155dc92ed5e201069665ff39669792475fe3cc1e8fe68d9e8ffc545be1dabda
Hash: a84814f3853c0b2267ebda44176c7cf9e1314b34852d301416af8063657bccd0

Block 2:
Timestamp: 1753952463.0588956
Data: {'voter_id': 'Voter2', 'vote': 'Bob'}
Previous Hash: a84814f3853c0b2267ebda44176c7cf9e1314b34852d301416af8063657bccd0
Hash: 6076505b107829d319f4882f5421d3162dba34b6c321ad3921f58012c5232e8b

Block 3:
Timestamp: 1753952463.0588956
Data: {'voter_id': 'Voter3', 'vote': 'Alice'}
Previous Hash: 6076505b107829d319f4882f5421d3162dba34b6c321ad3921f58012c5232e8b
Hash: 09a15067c877763131d0693e29ebb5ee1b3813c175441ca12bdd55b63b2eebd6

==== Vote Summary ====
Alice: 2 vote(s)
Bob: 1 vote(s)
```

**Figure 4.2: Blockchain Ledger After Vote Casting**

This screenshot shows the contents of the blockchain after several votes are cast. Each block contains vital information such as timestamp, vote data, the previous block's hash, and its own hash. This structure ensures vote integrity and immutability.

### 4.3 Vote Summary Table

```
Vote Summary Table:

+-----------+------------+
| Candidate | Total Votes |
+-----------+------------+
|   Alice   |      3      |
|    Bob    |      1      |
|  Charlie  |      1      |
+-----------+------------+
```

**Figure 4.3: Final Vote Summary Output**
The vote summary section displays the total number of votes received by each candidate, calculated from the ledger blocks. This is a terminal-based output providing real-time result computation.

### 4.4 Vote Count Bar Chart

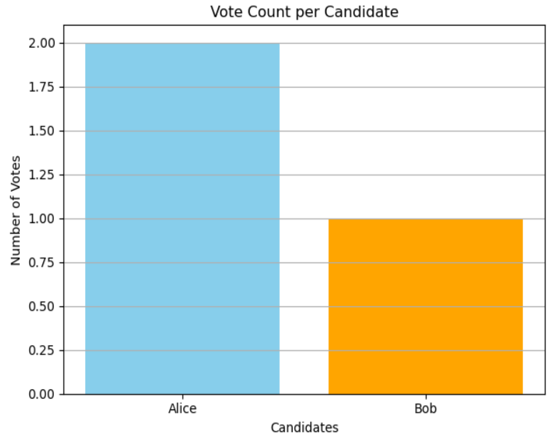


**Figure 4.4: Vote Count per Candidate**

The bar chart offers a clear and immediate view of the vote count for each candidate. It helps in understanding the margin or gap between the votes visually.

### 4.5 Vote Distribution Pie Chart Literature Survey

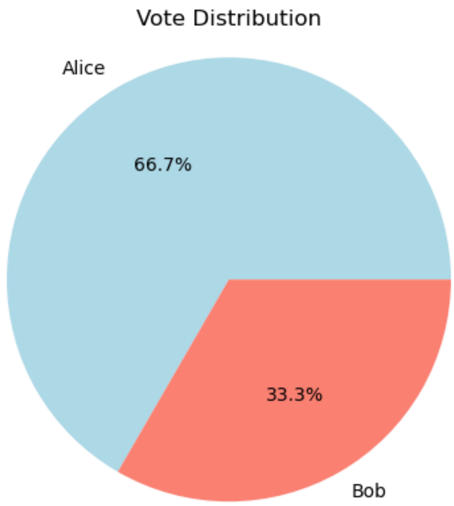


**Figure 4.5: Pie Chart of Vote Distribution**

This pie chart depicts the percentage share of votes received by each candidate. It helps in identifying the winning candidate visually in case of a majority.

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### 4.6 Blockchain Block Structure Diagram

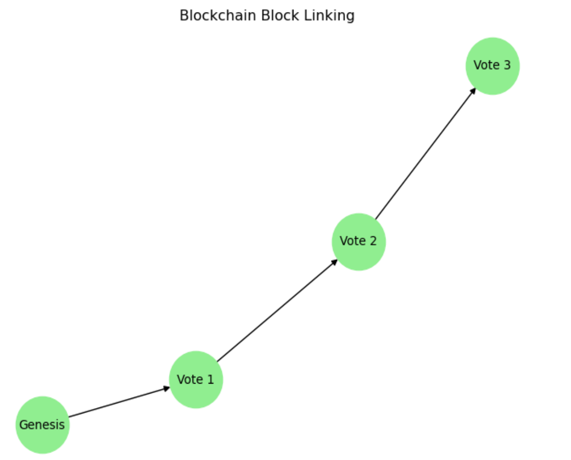


**Figure 4.6: Blockchain Structure Visualization**

This network graph represents the linking of blocks from Genesis to the last vote. Each arrow illustrates the hash linkage between blocks, highlighting the immutability and order of the blockchain.

### 4.7 Time-Based Voting Activity

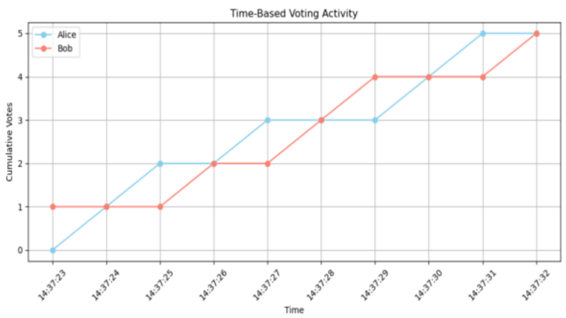


**Figure 4.7: Time-Based Voting Activity Line Chart**

This line graph illustrates the number of cumulative votes each candidate received over time. It provides insights into voting trends and behavior during the voting window.

**Interpretation:**

From the outputs and visualizations:

- Every vote is securely hashed and stored in the blockchain ledger.
- The vote summary validates the correctness of block data.
- Visualization charts provide a strong analytical view of voter behavior and result trends.
- The time-based chart ensures votes were cast in a sequential and non-overlapping manner.

These results verify the effectiveness of using blockchain for small-scale voting scenarios with built-in security, auditability, and transparency.

## 5 Limitations

- The system was tested in a local environment, not in a real-world distributed network.
- Voter authentication was simulated, not integrated with biometric or national ID verification.
- Scalability was not assessed with hundreds or thousands of voters.
- No integration with real blockchain platforms like Ethereum due to simplification for educational purposes.

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