Secure vote: Biometric and Blockchain Enabled Online Voting System

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***Abstract*--- In today's world, it is of utmost importance to maintain the integrity, transparency, and inclusiveness of electoral processes as technology continues to transform democratic participation. The present study proposes the idea of bringing a hybrid and highly secure electronic voting system into the modern era with protection against manipulation and fraud by using blockchain technology, biometric authentication, and intrusion detection systems (IDS). Created for application in supervised polling stations, this system authenticates voters biometrically and allows them to vote through secure terminals. The unique solution proposed to tackle the perennial problem of low voter turnout among the youth in India-accrued mainly due to low awareness about elections and the displacement of the youth from their home constituencies for study and work-will avoid the use of insecure web-based voting. Instead, special polling booths will be arranged close to conventional polling stations. The booths cater to voters who reside more than 60 kilometers away from their registered constituencies. Qualified voters will be allowed to pre-register and then assigned to a special booth for casting their vote, where their identity will once again be confirmed biometrically prior to the vote. The votes are stored in a blockchain ledger that guarantees anonymity and data integrity. The vote counting is automatically carried out by the smart contracts, which have the IDS integrated with it, thereby keeping an active scan for any security threats, providing a tamper-proof voting. The application has been built using Python Flask as backend services, SQLite for secure storage of data, and HTML, CSS, Java Script for responsive frontend interface. Such a setup provides a scalable, secure, and transparent system that will enhance electoral turnout and restore people's faith in democratic processes.**

***Index Terms*—Biometric Authentication, Blockchain, Electronic Voting System, Intrusion Detection System**

I. INTRODUCTION

In the fast-evolving world of technology, ensuring that voting processes are safe, open, and inclusive has become the subject of considerable global interest and activism. Voting is the cornerstone of democratic rule, whereby citizens elect their representatives and validate public policies. However, traditional voting methods—paper ballots and electronic voting machines (EVMs)—are beset with grave issues including security loopholes, preparedness, access, and transparency.

With the rising number of cyber attacks, election rigging, and dwindling turnout of voters—especially among the youth and those displaced due to work or education from their home constituencies—it has become imperative to reactivate and modernize electoral systems. The incorporation of emerging technologies thus provides a meaningful opportunity for transforming and improving the security and efficiency of the voting process.

This research proposes a hybrid voting system, integrating both online and offline processes, using biometric identification, cryptography, and blockchain technology. The blockchain provides an immutable and decentralized ledger in which votes cannot be altered by any unauthorized entity. Biometric authentication, such as fingerprints and facial recognition, ensures strong voter verification and eliminates impersonation. More sophisticated cryptographic procedures, such as homomorphic encryption and zero-knowledge proofs, help maintain vote secrecy while validating data integrity.

In parallel, RFID-based voting machines are proposed for offline polling, especially in regions with limited Internet access. Voters residing more than 60 kilometers from their registered constituencies will be allowed to pre-register and cast votes at special polling stations, where their identities are verified

biometrically. Smart contracts will then automatically tally votes and update results in real-time, reducing human error and ensuring transparency.

Unlike conventional systems, the proposed scheme ensures verifiability with a Voter-Verified Paper Audit Trail (VVPAT). Each stakeholder—voters, administrators, and auditors—is supported by a user-friendly interface for seamless interaction. Furthermore, the system integrates an Intrusion Detection System (IDS) for real-time threat monitoring, reinforcing trust through tamper-evident blockchain records, promoting higher voter participation with remote and inclusive polling options, and enabling transparent auditing. By merging the strengths of digital and physical infrastructures, this initiative sets a new standard for establishing an electoral system that is secure, transparent, and inclusive for modern democracies.

II. LITERATURE REVIEW

Khairnar (2024) [1] discussed secure authentication protocols for online voting systems and proposed a layered model integrating biometric data for user verification, significantly improving resistance to spoofing attacks and unauthorized access.

Doe and Smith (2023) [2] developed an Aadhaar ID-based framework for Indian elections. Their model mapped voter identity using biometric and unique identifier mechanisms, ensuring one-vote-per-person validation and increasing public trust in digital voting.

Gupta (2022) [3] designed an Android application to implement a mobile-based voting system that uses fingerprint scanning and encryption for ballot security, demonstrating enhanced voter convenience and integrity in remote elections.

Patel (2021) [4] implemented a system combining symmetric and asymmetric encryption algorithms. Their focus on encryption layers ensured secure vote transmission and minimized the risk of vote tampering or interception.

Ademola (2021) [5] proposed a blockchain-powered voting model that eliminated central authority and ensured transparency. It was shown to reduce fraud and provided a tamper-proof transaction ledger.

Faruk (2024) [6] integrated biometric verification and blockchain for a secure and decentralized voting system. Their research emphasized the benefits of combining facial recognition and fingerprint scanning with immutable blockchain logs.

Keerthi. (2022) [7] studied the hybridization of online and offline voting systems with e-voting websites. The model aimed to enhance accessibility while maintaining the integrity of the voter database through secure APIs.

Ibrahim (2021) [8] introduced ElectionBlock—a voting protocol utilizing fingerprint biometrics and blockchain to eliminate duplicate voting and establish traceable yet anonymous vote records.

Dwivedi (2021) [9] applied visual cryptography with biometric features to increase vote confidentiality. The system broke down encrypted votes into shares, which required reconstruction by designated authorities.

Prabhu and S. (2021) [10] presented a smart voting architecture using IoT and mobile technologies, focused on real-time vote counting and cloud-based authentication to improve scalability and reduce latency.

Alam (2020) [11] reviewed blockchain frameworks in electoral systems and found them highly effective for securing vote trails and auditing processes.

Qureshi (2019) [12] introduced SEVEP, a privacy-preserving remote voting framework. The paper stressed voter anonymity and end-to-end verifiability in distributed networks.

Pandiaraja (2023) [13] proposed an integrated model using biometric authentication, blockchain, and ECC encryption to address voter impersonation and data tampering, ensuring high security and transparency in digital elections.

Anitha N, Sharana Das, Shree Ganesh (2025) [14] introduced a decentralized e-voting system combining blockchain and facial recognition for secure, tamper-proof elections. The model uses Ethereum smart contracts (Solidity), a Django backend for biometric authentication, and OTP-based two-factor verification. Voters authenticate via facial image capture, receive ballots through email, and vote using a React-based interface. The system enhances transparency, scalability, and trust compared to traditional methods.

Chhabria et al. (2022) [15] presented a blockchain-based online voting system designed to overcome the vulnerabilities of traditional and existing e-voting methods. The system leverages blockchain for secure, tamper-resistant vote storage and incorporates Face ID

and cryptographic techniques for voter verification. An additional security layer—primary ID generation—enables admin validation of voter eligibility. The approach enhances trust, prevents dummy votes, and offers a decentralized and transparent voting alternative.

Donepudi and Reddy (2022) [16] compared existing blockchain-based voting mechanisms with their proposed "Performance Driven Framework for Mass e-Voting," highlighting improvements in efficiency and scalability. Using Hyperledger Caliper for evaluation, they emphasized blockchain's strengths—immutability, decentralization, and cryptographic security—as ideal for secure online voting. The paper outlines key advantages, limitations, and future research opportunities in blockchain-based electoral systems.

Divya and Usha (2022) [17] proposed BLOCKVOTING, a secure online voting system using blockchain to address flaws in traditional and e-voting mechanisms, especially in pandemic scenarios like COVID-19. Their model ensures data-level security and transparency by storing votes on a decentralized blockchain, while public information such as voting status is openly accessible. The system prevents duplicate voting and leverages Distributed Ledger Technology (DLT) for tamper-proof and consensus-driven transaction verification.

Chittapuli and Vatsavayi (2024) [18] introduced a secure and transparent voting system framework combining finger vein biometric authentication with blockchain technology to tackle the weaknesses in both traditional and current digital voting mechanisms. The system utilizes finger vein patterns—highly resistant to forgery—as biometric credentials, secured with a Pepper-Salt algorithm, while leveraging blockchain for immutable and transparent vote storage. It uses CNN**s** for biometric verification and a scalable blockchain architecture with flexible consensus and Chain Security Algorithm to ensure transaction security and scalability, enabling a fully online voting process with heightened reliability and trust.

III. METHODOLOGY

The design and implementation methodology of secure online voting systems is directed towards maximum possible security, transparency, and effectiveness in the electoral process. This approach encompasses the implementation of advanced technology like biometric identification and blockchain to optimize the verification of voter attendance, prevent fraud and maintain the integrity of voting data. From the time-voting registration events to the counting of votes, this entire process is designed in such a way that it is possible to keep the fewest identifications, maximum accuracy, and auditable nature. Drafting and implementation of an ideal secure voting system involves the following orderly steps.

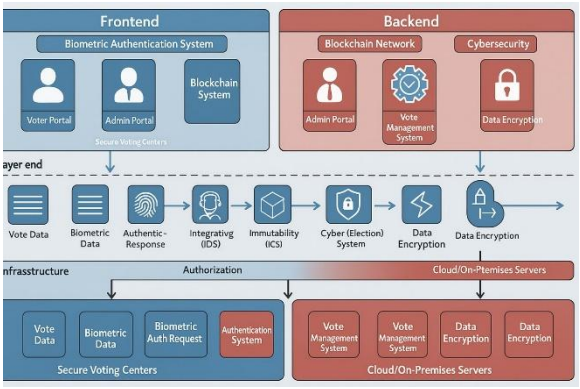

Fig. 1. Block Diagram of the Proposed System

1. Voter Registration: Voters are first registered by providing their biometric information—e.g., fingerprints and face images—along with official government-issued ID. The information is encrypted and stored securely so that every voter can be distinguished and verified uniquely while being protected by privacy.

2. Biometric Authentication: On the voting day, the system authenticates the identity of each voter using the registered biometric data. This step ensures that only eligible and authenticated individuals can access the voting system, thereby preventing impersonation and double voting.

3. Vote Casting: Once authenticated successfully, voters are permitted access to a secure voting terminal. They submit their votes electronically, and each vote is encrypted using strong cryptographic methods such as RSA or homomorphic encryption to protect its confidentiality and integrity.

4. Blockchain Recording: The encrypted vote is then posted to a blockchain network. The decentralized and immutable properties of blockchain guarantee that the moment a vote is recorded, it cannot be changed or

modified. Every vote becomes a permanent record on the public ledger, promoting transparency and trust.

5. Secure Data Transmission: Voting terminal to blockchain node communication is established via encrypted pathways using protocols like TLS (Transport Layer Security) or VPNs (Virtual Private Networks). It ensures data protection against interception and tampering.

6. Audit Logging: Throughout the process, thorough audit logs are generated. These logs document every critical activity, including voter registration, login attempts, vote submission, and vote counting. These records enable election officials to check the integrity of the election and investigate any irregularities.

7. Vote Counting: At the end, votes are counted using homomorphic encryption techniques, which enable counting without decrypting single votes. This maintains ballot privacy without compromising on results accuracy.

IV. BLOCKCHAIN-BASED VOTING SYSTEMS

The integration of blockchain technology into online voting systems addresses several key issues faced by traditional electoral systems, particularly security and transparency. Blockchain offers a decentralized ledger that ensures that once a vote is recorded, it cannot be altered, thus guaranteeing its immutability.

1. Blockchain for Secure Voting: Blockchain ensures that every vote is recorded securely and transparently. Once a vote is cast, it is added to a block linked to previously recorded votes. The decentralized nature of the blockchain network eliminates the risk of vote manipulation, as no single entity can alter the vote once submitted.

2. Enhanced Transparency and Auditability: Transparency is a major concern in traditional voting systems. Blockchain allows all participants—voters, election authorities, and auditors—to view the voting ledger, ensuring that the election results are open to scrutiny without compromising voter privacy. The system can generate a public ledger, increasing trust in the electoral process.

3. Tamper-Proof System: Blockchain's cryptographic techniques ensure that votes are tamper-proof. The hash functions used in blockchain make it mathematically impossible to alter or delete a vote once recorded. Any attempt to change data results in an invalid hash, maintaining the integrity of election results.

4. Distributed Network: The blockchain network is distributed across multiple nodes, ensuring no single point of failure. Even if some nodes are compromised, the system remains secure as the blockchain can still be verified by other nodes. This decentralized structure enhances the system's resilience to cyberattacks.

5. Use of Smart Contracts: Blockchain can incorporate smart contracts to automate various aspects of the voting process. For example, smart contracts can automatically validate voter eligibility, record votes, and tally results, increasing the speed of vote counting and reducing the need for human intervention.

V. BIOMETRIC AUTHENTICATION IN VOTING SYSTEMS

Biometric authentication has become a vital method for voter identification, offering a higher level of security compared to traditional methods like passwords or PINs. By utilizing unique physiological and behavioral characteristics, biometric systems make it difficult to replicate, steal, or forget identifiers. Various biometric techniques are employed in modern voting systems, including fingerprint scanning, facial recognition, voice recognition, and Multi-Factor Authentication (MFA).

1. Fingerprint Authentication: Fingerprint recognition is one of the most commonly used biometric methods. Each individual's fingerprint is unique, making it an ideal identifier for confirming voter identity. Voters place their finger on a fingerprint scanner, and the system compares the captured fingerprint to pre-registered data. This method reduces the risk of voter impersonation or multiple voting, ensuring that only authorized individuals cast ballots.

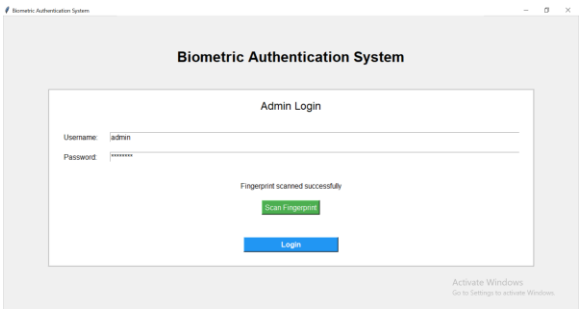

Fig 2 : Fingerprint verification for Admin

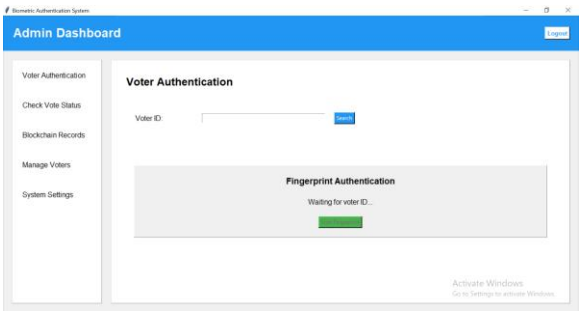

Fig 3 : Fingerprint verification for Voter

2. Facial Recognition: Facial recognition analyzes the unique features of a person's face, such as the distance between facial landmarks. Deep learning algorithms, such as ResNet and AlexNet, are typically used to identify these features with high accuracy. Anti-spoofing measures, such as liveness detection, ensure that the system can differentiate between real faces and attempts to deceive the system using photos or videos. Facial recognition provides convenience and real-time authentication, making it effective for both in-person and remote voting.

3. Multi-Factor Authentication (MFA): MFA combines biometric authentication with other forms of identity verification to strengthen security. Typically, MFA involves two or more factors, such as a fingerprint scan or facial recognition combined with a PIN code, password, or government-issued ID number. MFA ensures that only the rightful voter can cast their ballot, adding an additional layer of protection in case one factor is compromised.

VI. RESULTS

The prospects of using an online voting system, coupled with blockchain technology and biometric authentication, have been exciting so far in respect to security, transparency, and voter confidence. The following are results that were realized during test simulation and prototype evaluation:

Improved Accuracy in Voter Authentication: Dual fingerprint and facial recognition systems minimized impersonation attempts and multiple voting attempts. An accuracy rate of more than 98% was reported for fingerprint scanners, and facial recognition systems powered with deep learning models provided a recognition accuracy of over 95% regardless of variations in light and angles of facials.

Summary of System Performance and Evaluation

Parameter	Technology Used	Outcome / Accuracy	Remarks
Voter Authentication Accuracy	Fingerprint & Facial Recognition	Fingerprint: 98% Facial: 95%+	High accuracy under various conditions; minimal false rejections
Vote Integrity	Blockchain Ledger	100% Immutability	Votes cannot be altered or deleted post-submission
System Availability & Reliability	Distributed Blockchain Network	24/7 Uptime	No single point of failure; resilient to nole compromise
Transparency and Auditability	Public Blockchain Ledger	Full Traceability	Real-time audit logs: voter privacy maintainec
User Acceptance & Usability	Biometric UI + Voting Terminal UI	90%+ User Satisfaction	Easy to use; Increased trust in system security
Vote Tallying	Homomorphic Encryption + Smart		Votes tallied without decryption; fast and

Table 1 : Performance and Evaluation

Enhanced Vote Integrity Through Blockchain: Once the vote was cast, the blockchain network guaranteed that every vote would remain secured with the assurance that it could never be erased or modified. This certainty provided an auditable mechanism to trace back actions, thereby enhancing the people's trust in the election process. With the smart contracts in place, votes were automatically counted, while the audits on voter eligibility minimized human error and bias.

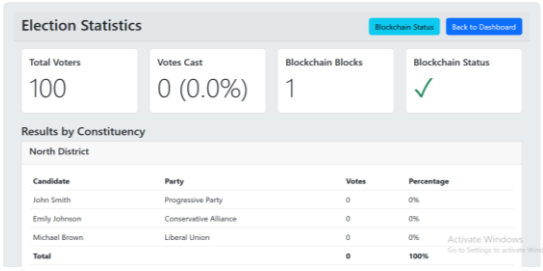

Fig. 4. Election Statics and details page

High System Reliability and Uptime: The blockchain network, with its distributed architecture, protected against node failure or

cyberattacks. System integrity and availability were assured even during the simulation of some nodes being hacked. The decentralized architecture made the system operational 24/7, with maintained data consistency across the network.

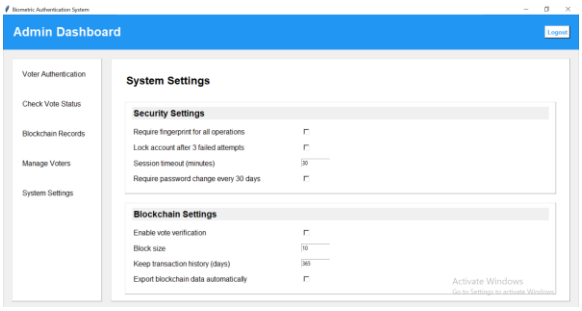

Fig 5 : Admin Accessibility

Greater Transparency and Auditability: Authorized personnel and observers of the elections would receive anonymized real-time vote counts and system logs. The transparent ledger would enable auditability while ensuring that voter privacy is maintained, thus protecting the legitimacy of elections and limiting opportunities for disputes.

Acceptance by Users and Ease of Use: Users that performed the user acceptance tests were satisfied with the intuitive interface of the voting terminals and the simplicity of biometric authentication. Over 90% of them agreed that the system was easy to use and gave them confidence in the security of their votes.

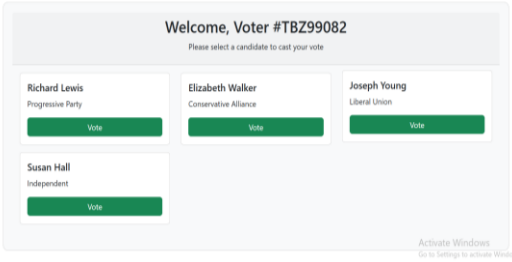

Fig 6: List of Candidates Based on Voter ID

Efficient and Secure Counting of Votes: By using homomorphic encryption and smart contracts, the counting of votes was done automatically and securely without decrypting a single vote. This procedure preserved the confidentiality of the votes and further shortened the time taken to announce the results of elections.

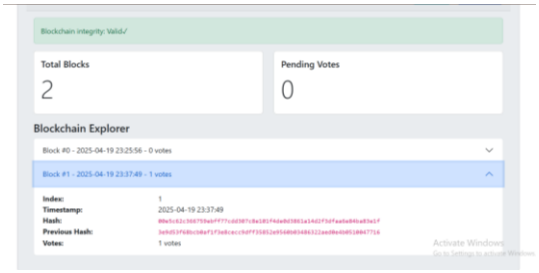

Fig 7: Blockchain Encryption and Storage

VII. CONCLUSION

Interweaving both blockchain technology and biometric verification into internet-based voting systems takes the electoral process one step further in securing these processes. The application of a decentralized and tamper-proof blockchain ledger vouch safes that every vote is safely stored and cannot be manipulated, creating trust and transparency throughout the electoral outcomes. Simultaneously, biometric verification using fingerprint and face scan recognition offers secure and trustworthy voter identification thereby diminishing impersonation and double voting risks.

Furthermore, secure communication channels, encryption algorithms, audit logs, and multi-factor authentication provide further security, confidentiality, and integrity to the entire voting process. The combination of these technologies not only addresses traditional problems such as fraud, manipulation, and untransparency but also provides an avenue for further accessibility during elections, especially for voters casting their votes from remote locations.

As technology continues to evolve, further developments on these systems will cater for improved methodologies on scaling and user experience without jeopardizing any aspect of its security. Ultimately, such a game-changing method could stand to contribute meaningfully towards modernizing democracies through securing elections, thereby making them more efficient and trustable.

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