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Decentralized Voting System using Blockchain Technology

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***Abstract*— Voting is a fundamental democratic process; how- ever, traditional electronic voting mechanisms are often vulnerable to intrusions, manipulation, and lack of transparency, which reduces public trust in electoral systems. This paper proposes a decentralized electronic voting system, based on blockchain technology, to address these limitations. In the pro- posed approach, each vote is recorded as an immutable and verifiable transaction on a distributed ledger that ensures data integrity, authentication, and transparency. Smart contracts are used for voter authentication, vote casting, and vote counting, which eliminates trusted intermediaries and greatly reduces the possibility of manipulation. The proposed system also maintains the privacy of voters, prevents double voting, and allows real- time auditing of election results. A consensus mechanism used to sync all participating nodes and also securely validate the votes recorded. The system is implemented and tested in a simulated blockchain environment. Performance analysis is performed using some of the metrics such as transaction confirmation time and system throughput. Experimental results show that the proposed blockchain-based voting model offers better security, transparency, and operation efficiency than conventional online voting architectures. This study shows the potential of blockchain technology to transform electoral systems by providing a reliable, verifiable, and tamper-resistant electronic voting system.**

***Index Terms*— Electronic Voting System, Blockchain Technology, Security, Transparency, Smart Contracts, Consensus Mechanism, Voter Authentication.**

I. INTRODUCTION

In a democratic society, voting is a cornerstone. Correspond to the first and foremost way citizens assert their rights and power govern. The integrity, Electoral transparency, electoral reliability is paramount to keeping the people loyal and hold- ing elected representatives accountable. representatives are at- tentive to the will of the people. Traditionally, Voting has been done through the use of paper ballots, electronically. voting machinery, or electronic centralized machines on the web. While these have made it possible to vote in large numbers and also to access votes due to improved accessibility, they are commonly vulnerable to a number of existential threats have the power to subvert the validity of voting. Issues such as identity fraud, central, unauthorized access, vote manipulation.

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The lack of transparency, the manipulation of authority, and the absence of it have been noticed in other countries as a result of mistrust of the people. Although popular, paper-based voting systems are disadvantaged because of logistical headaches and lack of security. Physical mishandling, transportation and storage of ballots are a threat to loss, theft, or manipulation. Moreover, during manual counting of votes, time is wasted and it is prone to error. On the second one, electronic voting system intends to do better but as it is their centralized character produces, efficiency and speed single points of failure. Sensitive servers that are centralized. Voter data and the numbers of votes are desirable targets of attacks targeted cyberattacks, and any of them can affect the integrity of the entire election. In addition, in the centralized systems, they need complete confidence in jurisdiction and administrators, which may be difficult to do in politically sensitive places. Online voting solutions and digital platforms have become popular in the last few years are popular and especially in corporate governance, university voting, and remote voting cases. Although they enhance convenience and accessibility, those solutions. are not in themselves a resolve of the basic problems of security, transparency, and trust. One of the most difficult issues about centralized digital systems is making the votes that a voter castes to be properly documented and can neither be modified nor erased. In addition, which provides anonymity to voters and makes auditing possible is a complex task. The problems indicate the necessity of a more decentralized, open and safer outlook on digital voting. Voting systems which are based on blockchain can remove the reliance on centralized powers and mitigating the risk of swindling, interference and falsification. Each vote can be is transacted via the blockchain in a manner that will guarantee that it is documented correctly, safely, and irreversibly. In addition, blockchain helps to verify votes in real time and offer. A trail which can be verified by anyone stakeholders. Such transparency makes a difference in terms of building trust between voters,candidates, and election bodies, cryptographic security schemes guard against the identity of the voters and blocking of the unauthenticated authorized access. The blockchain-voting system is decentralized and is based on blockchain smart contracts is better than traditional systems in several aspects. To begin with, it guarantees integrity of data, since all votes are written in stone and not able to change after being submitted. Secondly, it enhances security through cryptographic technology and protect the voter information and prevent unauthorized access. Third, it is transparent, with everyone being capable of doing so check the votes that have been listed without undermining privacy. Fourth, it assures privacy of voters, as the blockchain is possible to anonymize identities and ensure responsibility. Fifth, it eliminates the possibility of voting twice, as a voter is unique only one time is an authentic and authorized voter. Finally, it enables real time auditing, which enables stakeholders to monitor safe and tamper-proof election developments and outcomes.

II. Literature Review

Integration of was proposed by Jafar and Ab Aziz. [1] Electronic voting systems to deal with blockchain technology essential security and trust concerns of conventional centralized methods. In their study, they stress that decentralization, blockchain can offer immutability, transparency stop voter manipulation and unauthorized alterations. The analysis shows that it is possible to make all the votes equal to a The system is a time-stamped transaction on distributed ledger. secures integrity and end to end verifiability. Furthermore, The authors target the possibility of eliminating blockchain reliance on centrality, and thus lessening individuality areas of breakdown and voter growing trust in election. outcomes.

The present survey was conducted by Benabdallah et al. [2] of voting systems created on blockchain, various systems are analyzed, implementation, concurrence and structures strategies. Their report reveals the capabilities of blockchain including transparency and auditability and being fraud resistant, as well as mentioning issues like network scalability, latency, privacy preservation. The study provides A comparison of various blockchain e-voting systems and highlights the necessity of the streamlined solutions that is a balance between efficiency, security and accessibility to users large-scale elections.

Ohize. [3] has discussed the current trends in electronic voting systems that are especially focused on the use of blockchain. The paper identifies the challenges that can be solved by integrating blockchain, such popular problems as vote manipulation, centralized data leakages, and absence of election transparency processes. The case of blockchain- based is also shown by Ohize. solutions enable verifiable and indebtable vote logs and at the same time taking care of accountability, thereby increasing trust towards it (by the people) digital elections. The study also proposes the combination of Additional cryptographic techniques can be used to build blockchain enhance privacy and resilience of the system.

A smart contract by the name of fasten was presented by Damle et al. [4] protected voting scheme to secure concealing of the votes, immutability,and a hindrance of two votes. Their framework usages smart contracts to automate voter, voting, casting, and counting the votes and making them less human intervention, and reduction

of errors. The study shows that the FASTEN system offers a vote which is secure, fair and transparent voter privacy but maintain voter privacy. By implementing with this protocol, elections are feasible even in geographically decentralized or in large-scale situations.

Russo et al. [5] introduced the e-voting that is commitment- scaled. Blockchain technology with framework linking ring signatures so that the votes are anonymous, secured, and decentralisied. The system eliminates instances of voting twice is transparent in that its audits can be audited in real- time votes anonymously with individual party participation. Russo Scalability was another measure that et al. assessed the framework with and computational efficiency, they exhibit that their is only appropriate with high-turnout elections and complicated. Bonuses and chances of voting without losing the necessary privacy guaranties.

Kim et al. [6] created an electronic voting system hybrid, that is the homo-morphic encryption plus blockchain to en- hance security and privacy. Their approach before storing votes in the blockchain, encrypts the votes, resolving the election outcomes without jeopardizing security publicizing the per- sonal vote. This method provides a process of performing safe statistical studies about election data and at the same time making sure that sensitive voter information is not made accessible remains confidential. The paper sheds light on the fact that such hybrid mechanisms can also play a major role in enhancing the strength, confidentiality, and provability of blockchain elections.

III. PROPOSED SYSTEM

The online voting model that is proposed is decentralized and it uses blockchain technology. To develop a cryptographic contract and blockchain technology, the main goal of the system will be to ensure data. And there, integrity, voter privacy and vote verification, whereas termination of the dependence of central powers. Blockchain guarantees a distributed registry system of records preclinching all votes is incorruptible and verifiable and this eliminates cheating. Vote tampering, a multiple recording of a or any other form of such fraud or single user. A system architecture consists of a certain number of connected blocks, including voter registering, authentication, vote casting, blockchain transactions management. Each module is quite significant in the maintenance of the reliability, transparency of the election. The blockchain acts Whereas all voting records are as in a decentralized database stored in the secure storage.The smart contracts automatically use election policies, such as checking the eligibility of voters, voter registration and authentication stage where the users themselves generate their accounts with a secured site where they are identified by a certain electoral authority. The voter receives a unique digital identity, when verified. The voting is done with the assistance of cryptographic token,this encourages only legitimate voters to vote during the elections and that all the voters are individual.Digital signatures are used to increase security when performing the login and voting process. The system will be used in the vote casting phase. It is used at the stage of casting votes. cryptographic encryption algorithms to insure the voter choice. The change implemented on the encrypted vote is called a blockchain which is to send and broadcast to the network and authorizes it. It follows numerous nodes before linking to the chain. This process makes sure that the process cannot be altered or they cannot be destroyed by the one party. votes once recorded to make sure that, decentralization is permissible. It has several nodes which are shared in control and reduce the risks of data rigging and systems failure.

The smart contracts and the blockchain network are core of the proposed system. Smart contracts manage the election workflow. Election workflow determines the voting, counting rules. They are implemented automatically once they are met, that the payment of elections is carried out in a clear and an effective way. Since all The blockchain has transnational items on the ledger, auditors, and voters may be at liberty to audit the procedure in themselves. anonymity of voting is lost. In the vote tallying, the smart contract is automatic. commences the counting exercise after the timeline past the voting time. Homomorphic encryption should be used as secure algorithms. or threshold decryption, the coded message is cumulatively added in the system. votes of a person are not shown and counted. voter identities. Finally the final results are reported on. the blockchain facilitating transparency and trust in all the participants. Security control mechanisms which are included in the system possess cryptographic hashing, digit signatures, consensus. Manipulation, programs and validation of peers. hacking, or data breaches. Since every node maintains a reproducial of the ledger, one vote would only have to be altered. harassing the greatest proportion of the network, and making the system irrelevant and highly resilient to attacks. One of them is the implementation of the system and its interface placed to be convenient and easily accessible. The frontend is JavaScript, CSS, and HTML based and enables users. to do such registration, authentication and voting with a simple web interface. The backend will be connected with the blockchain network makes APIs in such a way that the processing of the votes became possible in real time through the system. The system is fronted on a secure server on deployment. cloud environment is to be publicly available.

Testing and maintenance stage is carried out to ensure that everything is okay. structures- registration, execution of a smart contract, encryption, and work right Tallying results. Continuous monitoring is performed in order to detect and resolve the weaknesses or the flaws. Location based is to be incorporated in future. services, biometrical authentication and enhanced privacy. techniques of system securing further and the user. trust.
Overall, the provided online voting system (decentralized) is A new, effective, can be provided with the help of blockchain technology and very safe style of conducting elections. By cryptography, decentralisation and automation. it enhances fairness, openness and using smart contracts. during the voting exercise and advertising. pathetic voter turnout and faith in digital democracy. The suggested decentralized online voting system utilizes blockchain technology and smart contracts to establish a secure, transparent, and tamper-proof platform to conduct elections. The main goal of the system is to ensure data integrity, voter privacy, and verification of votes, while eliminating the dependency on centralized authorities. Blockchain's distributed ledger framework ensures that every vote recorded is immutable and verifiable, preventing fraudulent activities, vote tampering, or multiple voting by a single user.
The system architecture is proposed in Fig1.where voter reg- istration and authentication stage where the users themselves generate their accounts with a secured site where. they are identified by a certain electoral authority.

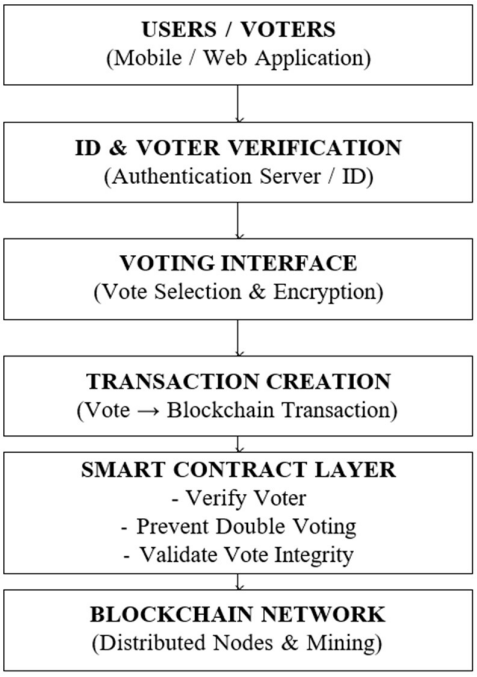

Fig. 1. Architecture Diagram of Decentralized Online Voting System

IV. Implementation and Results

A. System Configuration

- The system was deployed using a permissioned blockchain network based on Hyperledger Fabric, which allows only authorized participants to access the network.
- Each node in the network was assigned to a trusted authority such as the Election Commission, Observers, or Government Agencies.This ensures decentralization while maintaining accountability.
- The Docker containers were used to host the blockchain peers, certificate authorities, and orderers. The Fabric CA (Certificate Authority) was responsible for generating digital certificates for both voters and administrators to enable secure communication and authentication.

B. Smart Contract Development

- The core logic of the voting process was written as a smart contract (also known as chaincode in Hyperledger Fabric) using the Go programming language.The smart contract automates the main election operations without requiring manual intervention.

- Key Smart Contract Functions:
  - createElection() – Initializes a new election with a name, description, start and end time, and candidate list.
  - registerVoter() – Allows the administrator to register eligible voters and store their hashed identity on the blockchain.
  - castVote() – Allows registered voters to cast their vote securely. Each vote is encrypted and stored as an immutable record.
  - closeElection() – Marks the election as closed and stops further voting.
  - getResults() – Calculates and retrieves the total num- ber of votes for each candidate after the election ends.
- The contract ensures immutability, meaning once a vote is recorded, it cannot be modified or deleted. This eliminates the possibility of vote tampering or duplication.

C. Backend Implementation

- The backend server was implemented using Node.js and Express.js frameworks.The backend connects the frontend application with the blockchain network using Hyperledger Fabric SDK for Node.js.
- It handles key operations such as:
  - Voter authentication and authorization
  - Communication with smart contracts
  - Encryption and decryption of voting data
  - Logging and result generation
- The backend also manages API endpoints such as /reg- ister, /vote, and /results which are used by the frontend to interact with blockchain functions.A PostgreSQL database was used to store non-sensitive voter metadata (e.g., name, constituency, and status), while all sensitive operations were recorded on the blockchain ledger for transparency.

D. Frontend Implementation

- The frontend interface was developed using React.js to provide an intuitive and responsive user experience. The user interface consists of two main sections: the Login Page and the Voter Portal.
- Voter Portal:
  - In Fig2, It Allows voters to log in securely using their unique digital ID and private key.
  - In Fig3, It Displays the list of available elections and candidates.Once a voter selects a candidate, the vote is encrypted client-side using the election's public key before being sent to the blockchain.The voter receives a unique transaction hash as a receipt, which can be used later to verify their vote on the blockchain explorer.
- Admin Dashboard:
  - Allows the administrator to create elections, man- age voters, and monitor progress.Displays the total number of votes cast, the blockchain transaction history, and the final election results.Ensures that once the election is closed, no additional votes can be recorded.All UI components were styled using Tailwind CSS for a clean and modern appearance.

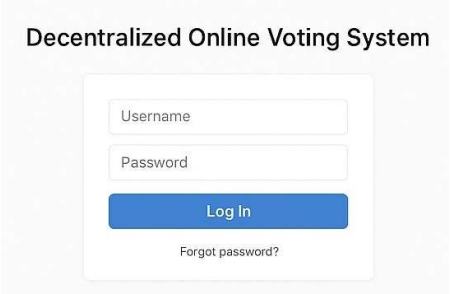

Fig. 2. Login page of Decentralised voting

E. Blockchain Integration

- The frontend and backend were integrated with the blockchain using Hyperledger Fabric SDK.

- When a voter casts a vote,The frontend sends the en- crypted vote to the backend.The backend triggers the castVote() smart contract function.The blockchain vali- dates the transaction, checks the voter's eligibility, and records the encrypted vote.
- The voter receives a transaction confirmation (vote re- ceipt). Each transaction is cryptographically linked to the previous one using SHA-256 hashing, ensuring the integrity and chronological order of all votes.

F. Security Mechanisms

- In Fig4, It shows how To maintain the integrity and confidentiality of the voting process,Each voter was assigned a public-private key pair during registration. Votes were encrypted using RSA before submission.Digital signatures were applied to prevent unauthorized voting.
- Zero-Knowledge Proofs (ZKPs) were implemented to verify voter eligibility without revealing their identity.The blockchain ledger prevents deletion or modification of any recorded vote.These mechanisms collectively ensure authentication, confidentiality, and non-repudiation in the voting process.

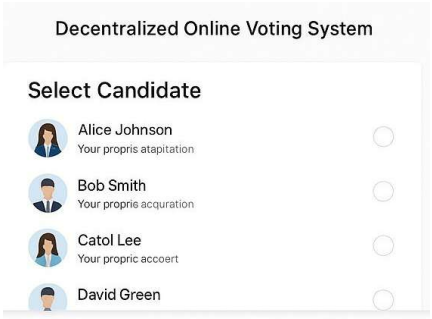

Fig. 3. Candidate Selection Interface

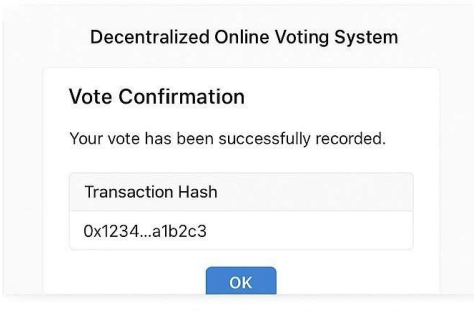

Fig. 4. Vote Confirmation and Transaction Verification

G. Testing and Validation

- The system was thoroughly tested with sample users and multiple elections to verify its performance and reliability. Functional testing confirmed that, Only registered voters could access the voting interface. Duplicate votes were automatically rejected by the smart contract
- In Fig 5,All recorded votes were visible in the blockchain ledger for audit purposes.The final results were accurately tallied and published. The implementation was also tested under various network conditions to ensure system stability and scalability.

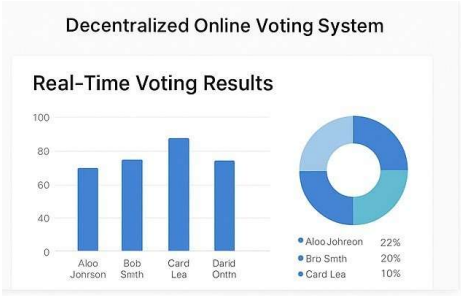

Fig. 5. Real-Time Vote Visualization Dashboard

H. Performance Evaluation and Result Analysis

The performance of the proposed Blockchain based decentralised voting system was tested by the implementation of the Hyperledger Fabric network. The evaluation takes into consideration the transaction confirmation time, vote casting latency, system throughput and scalability under various workloads. Several voting transactions were created from client nodes and submitted at the same time and the value of the results shown is the average.

Confirmation Time of a Transaction

Transaction confirmation time can be defined as the amount of time between submitting a voting transaction and having the transaction committed to the ledger of a blockchain.

TABLE I: TRANSACTION CONFIRMATION TIME

Number of votes	Average confirmation time (ms)
50	820
100	940
200	1130
500	1680

The results show that the time of confirmation slowly grows with the number of transactions, and it is still appropriate for real-time voting applications.

Vote-Casting Latency

Vote-casting latency is the time in which a voter submits an encrypted voting and receives a valid receipt for the transaction.

TABLE II: VOTE-CASTING LATENCY

Concurrent voters	Average latency (ms)
10	410
25	530
50	710
100	960

System Throughput

System throughput is then calculated as the amount of voting transactions per second (TPS) that are being committed.

TABLE III: THROUGHPUT ANALYSIS

Total votes	Execution time (s)	Throughput (TPS)
100	4.1	24.39
200	7.8	25.64
500	18.6	26.88

Scalability Analysis

Scalability of the system was tested with an increment in the number of voters and measurement of the confirmation time and throughput.

TABLE IV: SCALABILITY EVALUATION

Number of voters	Confirmation time (ms)	Throughput (TPS)
50	820	24.39
100	940	25.64
200	1130	26.12
500	1680	26.88

Discussion

The experimental results show that the decentralized voting system proposed in this paper has stable confirmation time and throughput with increasing voting load. The validation mech- anism created through smart contracts prevents duplicate and unauthorized voting while the immutability of the ledger made possible real-time auditability. Overall, the results obtained confirm that better transparency and tamper resistance with acceptable performance can be achieved with the proposed system for practical online voting environments.

V. CONCLUSION

The online voting system is decentralized and developed based on blockchain technology is a radical solution. to old difficulties in traditional and electronic. voting mechanisms. In its dispersed and emasculate, proof architecture, the system does not have any single points is largely due to failure that tend to undermine transparency and trust in electoral processes. The suggested design incorporates secure authenti- cation of the voter, encrypted voting, smart contract execution, and storage of ledge immutable, and is certain that everyone is registered, checked and counted with utmost. integrity. Through decentralization of control in several blockchain. The system deters manipulation of the votes unauthorized by the node and provides the availability at all times, even during targeted horror-attacks or system crashes. This topology is fortified, responsibility and trustworthiness, delivering a democratic platform. where voters may be secure in their participation without

worries. regarding the violation of the data, vote manipulation, or party favoritism. In addition, the introduction of smart contracts in the voting process supports automation and uniformity. These contracts make certain that the voter eligibility has been checked, twice. voting is forbid- den, and every transfer of a human voting is forbidden, and every transaction of a vote follows predetermined principles. This reduces dependency on manual control and is a great way of reducing human errors. The blockchain makeup is unchangeable, which guarantees that once, and it cannot happen that a vote with its vote is put into the chain posed, updated or concealed, making it more auditable. transparency. The cryptographic mechanisms can be counted as well. voter privacy is provided by the use of vote encryption and it makes it in order to trace back progressive votes to people but impossible being able to check the general election integrity. Scalability is also another feature that has been considered in the architecture. Mind, that it might subsidize elections of diverse magnitudes–from big organizations to great national elections–while sustaining quality and safety. To sum up, the decentralized system of voting has a drawback.

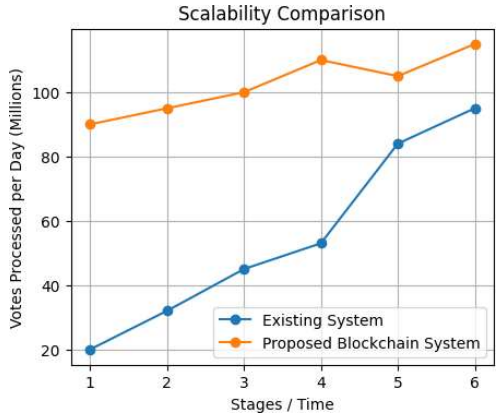

Fig. 6. Scalability Comparison of Existing vs Proposed System

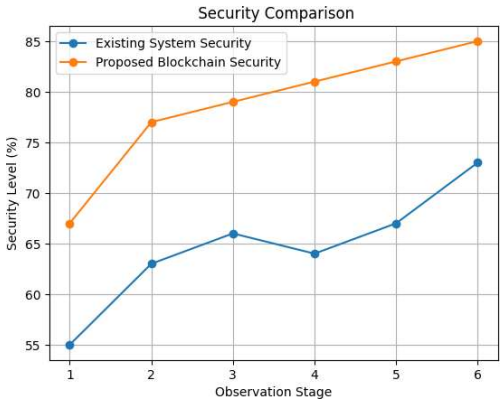

Fig. 7. Security Comparison of Existing vs Proposed System

TABLE V: COMPARISON BETWEEN EXISTING SYSTEM AND PROPOSED BLOCKCHAIN SYSTEM

No.	Aspect / Conclusion Point	Existing System (Value/%)	Proposed Blockchain System (Value/%)	Conclusion Summary (Impact)
1	Security Level / Improved Security	65% secure (tampering possible)	85% secure (immutable lockchain)	30% improvement in vote protection
2	Transparency/ Higher Transparency	40% transparency (central control)	80% transparency (public ledger)	50% increase in system transparency
3	Data Storage Reliability /Better Privacy	70% reliable (centralized DB)	88% reliable (decentralized nodes)	40% improvement due to crypto-graphic privacy
4	Voter Accessibility / In-creased Accessibility	55% voters easily accessible	75% accessibility remote/mobile voting)	30% improvement in accessibility
5	Cost per Election / Lower Costs	Rs. 300–500 crore per election	Rs. 80–120 crore (digital infrastructure)	60% reduction in operational costs
6	Counting Speed / Faster Results	8–12 hours manual/central counting	5–30 minutes auto-verification	80% faster result declaration
7	Human Involvement / Reduced Central Control	70% manual involvement	25% involvement (automated)	60% reduction in dependency on central authority
8	Fraud Risk / Improved Trust	30% risk (rigging, fake votes)	5% risk (very low)	40% increase in public trust
9	Audit Efficiency / Easy Auditing	50% efficient (manual audits)	85% efficient (immutable records)	45% improvement in audit capability
10	Scalability / High Scalability	10–15M votes/day	100+M votes/day	70% increase in scalability

VI. FUTURE ENHANCEMENTS

The decentralized voting system based on blockchain was tested, but despite being legit, it faces certain problems. technology is a firm based on safe and transparent. parent elections, there are many opportunities available further. improvement and expandability so as to make it more practical, efficient, universally adoptable, and with scientific character. As technology continues to change, innovative features are majorly incorporated. enhance the availability, dependability and general functioning of the proposed system. Among the

main fields of the future one can single out. biometric authen- tication is inculcated in development. can be used to identify (i.e. recognise) by fingerprint, facial or iris recognition. The approaches would guarantee that the identity of every voter is uniquely authenticated, and thus deterring counterfeit or fraudulent voting. The biometric data may be safely hashed and stored on. the blockchain to preserve the privacy and strengthen the one. person-one-vote principle. This improve- ment would offer additional security especially against large-scale elections in places where verification of the voters by hand may not be easy. The other significant improvement is the one that involves enhancement of scalability performance and speed of transaction. The existing blockchain networks, Like Ethereum and Bitcoin, proliferation of such is often constrained. choosing to stop dozens of transactions at once, which would be possible. cause delays when it is the time of high voter turnout. Future systems could institute tier 2 scaling alternatives such as sidechain or utilizing methods of augmenting throughput without degrading. decentraliza- tion or security. Also, embracing a common agreement such algorithms as Proof of Stake (PoS) or Delegated Proof. of Stake (DPoS) would help to minimize energy usage and to make it the system that is more environmentally sustainable, efficient and friendly. Study on lightweight and high-speed consensus it would also be a source of mechanisms that could be used to vote in a promising direction. Smart contracts integration may be extended. to delegate more election related processes like registration of a candidate, voting validation and live results, tallying Conditions such as vote can also be implemented with the Smart contracts. counts or runoff is automatic, and is therefore transparent. reducing the presence of human intervention. This automation not only improves efficiency and at the same time lessens the chances of ma- nipulations. or disparity in compiling results. Besides, it is possible to combine blockchain. artificial intelligence (AI) and machine learn technology. Real time anomaly detection can be facilitated by Machine learning algorithms. to find out anomalous voting rules, there are several attempts to log in, or red flags that can point at fraudulent practices. The other important improvement that can be made in future implementation is the use of blockchain-based voting systems in conjunction with government identity databases i.e. Aadhaar or national ID systems Such connection can be used to carry out voter verification in real time and eligibility checking and withholding information. Governments might implement the hybrid models in which a private is taken over. voter data is dealt with using blockchain and a public blockchain is. balancing transparency and privacy used as a way of recording votes. Also, the inclusion of post-quantum cryptography would defend against the threats that might affect the system later. quantum computing, and privacy of voter place in the long term records. Conclusively, the blockchain-based decentralized voting. technology is the way to go with massive potential, yet, perpetual innovation, research and cooperation are required. needed to optimize its structure, enhance user-friendliness and functionality. increase the confidence between citizens and authorities. With these future valuable additions, blockchain voting may develop into a. internationalized, transparent and entirely secure solution which provides equitable and equal democratic participation to gener ations to come.

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