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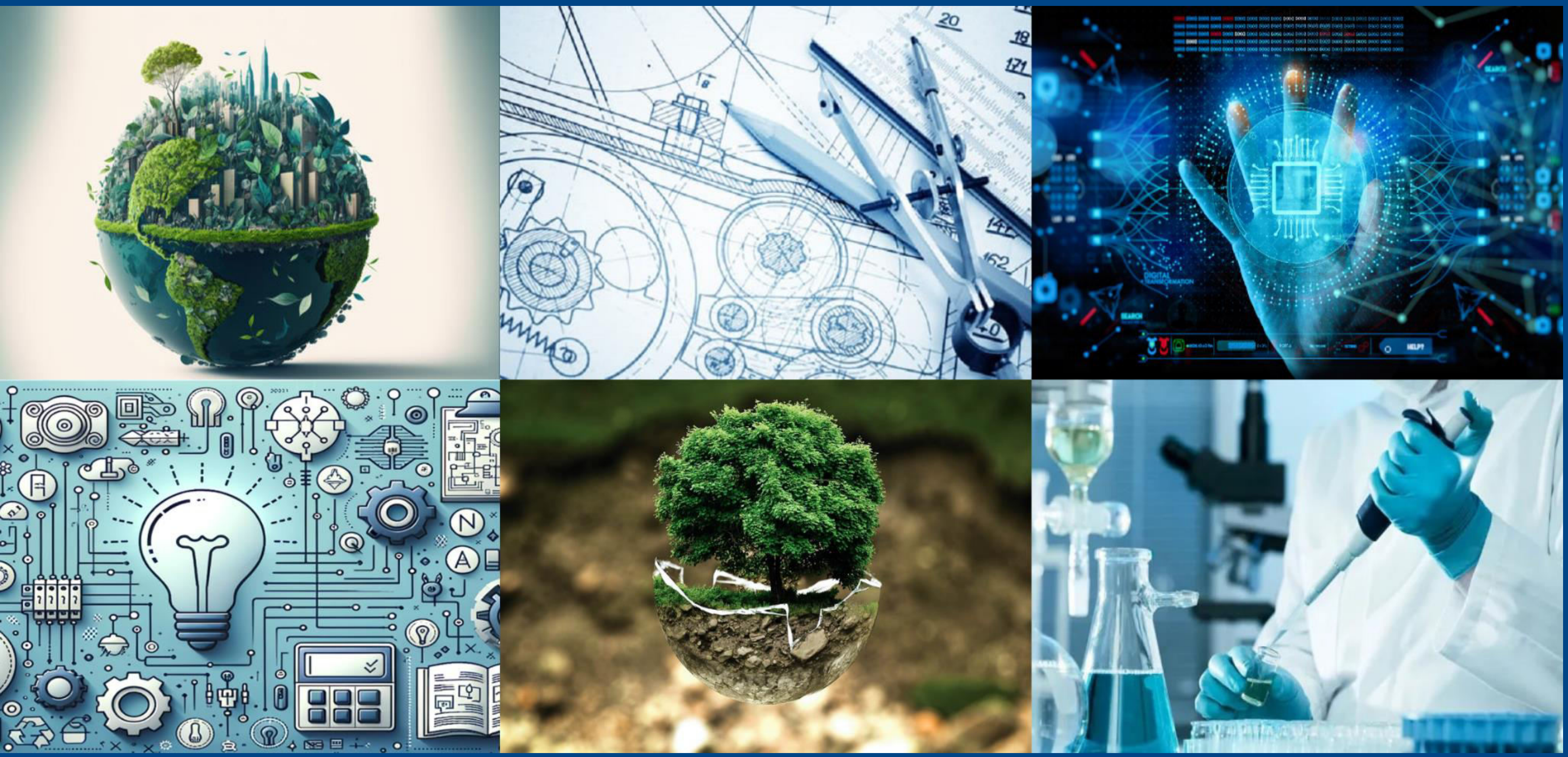

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Secure Block chain-Based Remote Voting System with Biometric Authentication and AI-Powered Monitoring

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ABSTRACT: This paper presents a secure blockchain-based remote voting system that ensures voter identity verification, vote integrity, and transparency through advanced technologies. The system integrates Aadhar & Voter ID based authentication, multi-factor biometric verification (facial and fingerprint recognition), and HMAC-SHA-256 encryption to provide a tamper-proof and efficient voting process. Upon the successful verification, a One-Time URL (OTU) is generated, encrypted using HMAC-SHA-256, and securely sent to the voter. This OTU is tied to the voter's session and stored on a blockchain ledger using Polygon, ensuring immutability and traceability. The voting process involves facial recognition and fingerprint matching to confirm voter identity before casting a vote. The system also implements AI-powered real-time monitoring using OpenCV and TensorFlow to detect suspicious activities such as the presence of external devices or multiple faces. Furthermore, Zero-Knowledge Proofs (ZKPs) maintain voter privacy while allowing vote authenticity verification. Each vote is recorded on the blockchain through smart contracts, facilitating automated vote counting and auditable transparency. By combining robust encryption, biometric authentication, and blockchain technology, the system provides secure, scalable, and accessible remote voting while maintaining voter privacy and electoral integrity.

KEYWORDS: Aadhaar & Voter ID Authentication, One-Time URL (OTU), Facial Recognition, Fingerprint Authentication, Real-Time Monitoring.

I. INTRODUCTION

Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think, learn, and perform tasks autonomously. AI systems are designed to analyse data, recognize patterns, make decisions, and even adapt to new situations with minimal human intervention. With rapid advancements in computing power, data availability, and algorithmic improvements, AI has become an integral part of various industries, revolutionizing the way we work, interact, and solve problems. At its core, Artificial Intelligence refers to the simulation of human intelligence in machines that are programmed to think, reason, and learn like humans. Rather than being explicitly programmed for specific tasks, AI(Artificial Intelligence) systems use algorithms and vast amounts of data to recognize patterns, make decisions, and improve their performance over time.

Artificial Intelligence encompasses a wide range of technologies, including machine learning, natural language processing, computer vision, and robotics. These technologies enable AI systems to perform complex tasks, such as speech recognition and face detection, with remarkable accuracy. we will delve into the intricacies of Artificial Intelligence, exploring its various applications across industries, its potential benefits and challenges, and the ethical considerations surrounding its use. So, join us as we unravel the mysteries of AI and its transformative power in our world today.

II. SYSTEM MODEL AND ASSUMPTIONS

The proposed system is a secure Aadhaar-based blockchain remote voting platform designed to address the limitations of traditional and existing e-voting systems. It integrates multiple components to ensure voter authenticity, vote privacy, and election transparency. Voter authentication is achieved through a streamlined multi-factor process that combines Aadhaar and Voter ID verification, OTP validation, and biometric checks such as facial recognition and fingerprint scanning. Once authenticated, the system generates a unique One-Time URL (OTU) for each voter, allowing secure and single-use access to the voting portal. AI-powered monitoring continuously captures and analyzes the voter's environment using image recognition techniques to detect suspicious activity, such as the presence of multiple faces or unauthorized devices.

Votes are encrypted and submitted via smart contracts to a tamper-proof blockchain (Polygon or Hyperledger Fabric), ensuring immutability and verifiability. Zero-Knowledge Proofs (ZKPs) are used to maintain voter privacy while allowing vote verification without exposing the vote's content. The system also includes a backend administration and monitoring module for real-time tracking, fraud detection, and blockchain auditing.

It assumes that all voters possess Aadhaar credentials, have access to an internet-enabled device with biometric capabilities, and that the backend services such as UIDAI APIs, OTP delivery systems, and blockchain infrastructure are fully operational and secure. This model ensures a scalable, transparent, and device-independent remote voting experience.

III. EFFICIENT COMMUNICATION

Efficient communication in the proposed Aadhaar-based blockchain remote voting system is achieved through the seamless integration of various modules that ensure secure, real-time, and low-latency interactions between the voter, authentication services, and the voting platform. The system uses One-Time URLs (OTUs) to create a unique and secure communication session for each voter, reducing the risk of session hijacking or duplicate voting attempts.

Communication between modules such as Aadhaar authentication, OTP services, and biometric verification is streamlined using encrypted APIs and JSON Web Tokens (JWT), ensuring fast and secure data exchange. Additionally, the use of cloud services and decentralized blockchain nodes (Polygon or Hyperledger Fabric) minimizes delays in vote storage and validation by distributing workloads efficiently.

AI-powered monitoring operates concurrently with the voting process, enabling real-time anomaly detection without interrupting the user experience. This modular and parallel communication structure reduces system latency, enhances scalability, and ensures that even during peak voting periods, the platform maintains high responsiveness and data integrity. Overall, the design supports reliable and secure communication flow across all components, ensuring transparency and trust in the remote voting process.

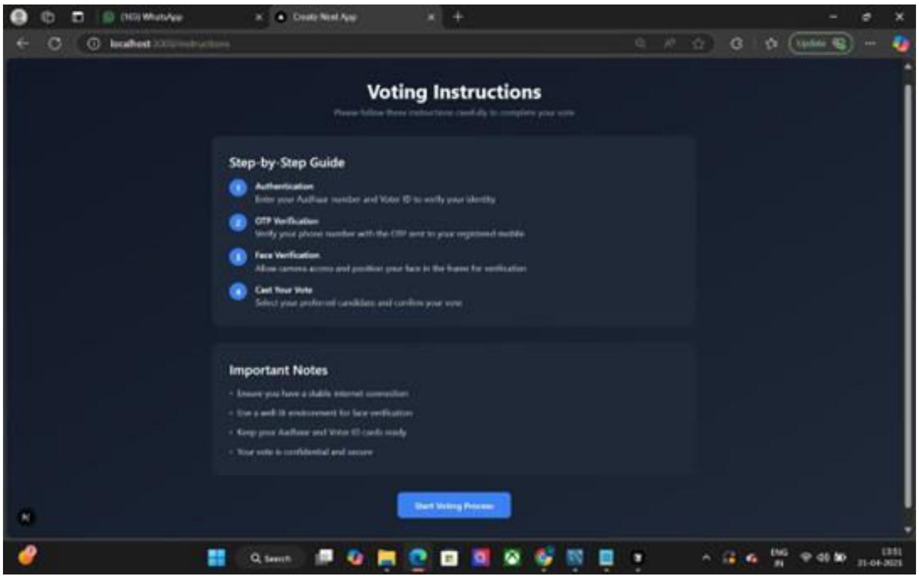
IV. SECURITY

Security in the proposed Aadhaar-based blockchain remote voting system is established through a multi-layered approach that ensures the integrity, confidentiality, and authenticity of the entire voting process. The system incorporates Aadhaar-based identity verification, OTP validation, and biometric authentication (facial recognition and fingerprint scanning) to prevent unauthorized access and impersonation.

Votes are encrypted before being submitted and are stored on a tamper-proof blockchain network such as Polygon or Hyperledger Fabric, ensuring that once a vote is cast, it cannot be altered or deleted. To maintain voter privacy while allowing verification, Zero-Knowledge Proofs (ZKPs) are used, enabling vote validation without revealing the vote content.

Additionally, real-time AI-powered monitoring detects suspicious behaviors such as multiple faces or device anomalies, immediately alerting the administration module to prevent fraud. All data transmission between modules is secured using AES-256 encryption and protected by secure communication protocols like HTTPS and JWT tokens. Regular blockchain auditing and smart contract validations further reinforce system transparency and safeguard against vote manipulation or cyberattacks. Collectively, these security measures ensure a highly secure, trustworthy, and tamper-resistant remote voting environment.

V. RESULT AND DISCUSSION



Voting Instructions

Please follow these instructions carefully to complete your vote

Step-by-Step Guide

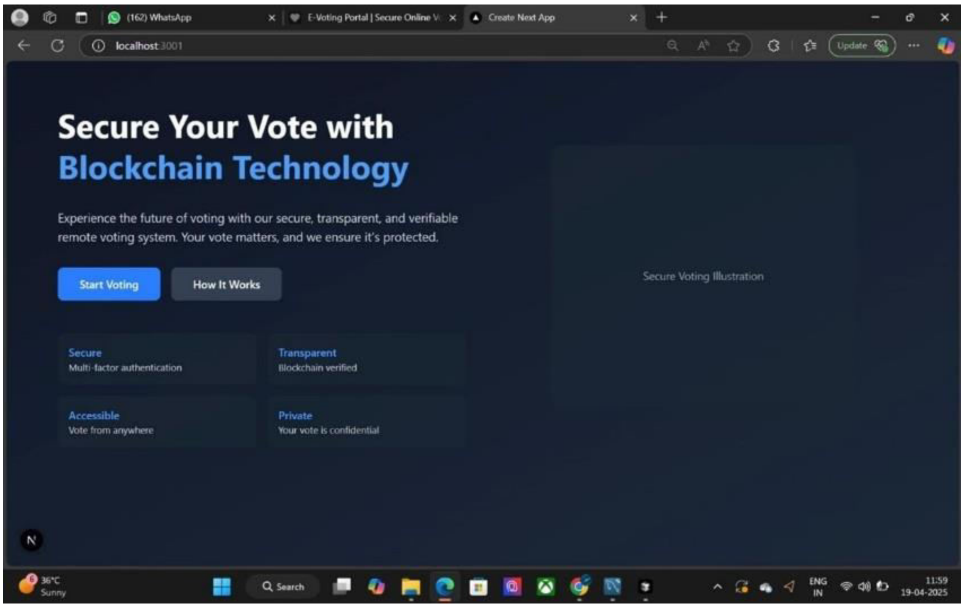
1. Authentication
   Enter your Aadhaar number and Voter ID to verify your identity
2. OTP Verification
   Verify your phone number with the OTP sent to your registered mobile
3. Face Verification
   Allow camera access and position your face in the frame for verification
4. Cast Your Vote
   Select your preferred candidate and confirm your vote

Important Notes

- Ensure you have a stable internet connection
- Use a well lit environment for face verification
- Keep your Aadhaar and Voter ID cards ready
- Your vote is confidential and secure

Fig. 1 Instruction page

In the fig 1, it displays voting instructions for an online system, outlining steps like authentication, OTP verification, face recognition, and vote casting. It also emphasizes important notes such as having an internet connection and keeping Aadhaar and Voter ID details ready.

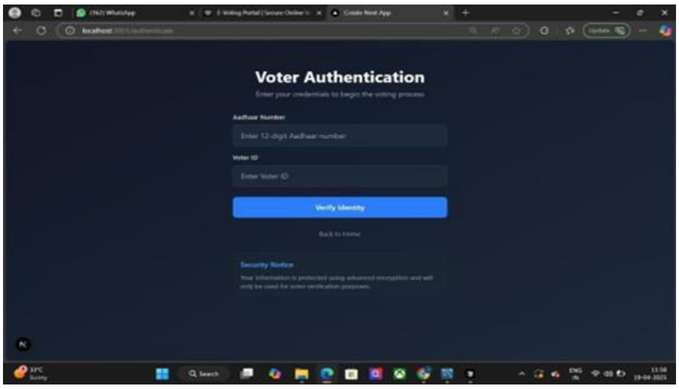


Secure Your Vote with Blockchain Technology

Experience the future of voting with our secure, transparent, and verifiable remote voting system. Your vote matters, and we ensure it's protected.

Fig. 2 Start page

In the fig 2, The interface promotes secure and transparent remote voting using blockchain technology with features like multi-factor authentication and confidentiality.



Voter Authentication

Enter your credentials to begin the voting process

Aadhaar Number: Enter 12-digit Aadhaar number

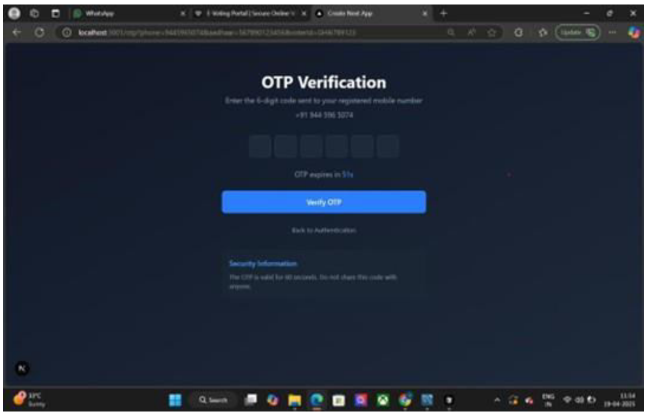
Voter ID: Enter Voter ID

Security Notice

Your information is protected using advanced encryption and will only be used for voter verification purposes.

Fig. 3 voter authentication page

In Fig 3, The page facilitates voter authentication by verifying Aadhaar and Voter ID details to begin the secure voting process



OTP Verification

Enter the 6-digit code sent to your registered mobile number

+91 944 596 5074

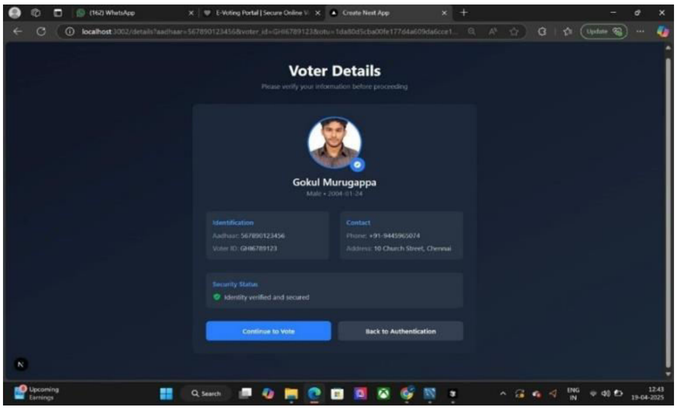
OTP expires in 51s

Security Information

The OTP is valid for 60 seconds. Do not share this code with anyone.

Fig. 4 OTP verification page

In Fig 4, The screen shows the OTP Verification step, where the user must enter a 6-digit code sent to their registered mobile number. It ensures secure user identity validation before proceeding in the voting process.



Voter Details

Please verify your information before proceeding

Gokul Murugappa

Male • 2004-01-24

Identification

Aadhaar: 567890123456

Voter ID: GHI6789123

Contact

Phone: +91-9445965074

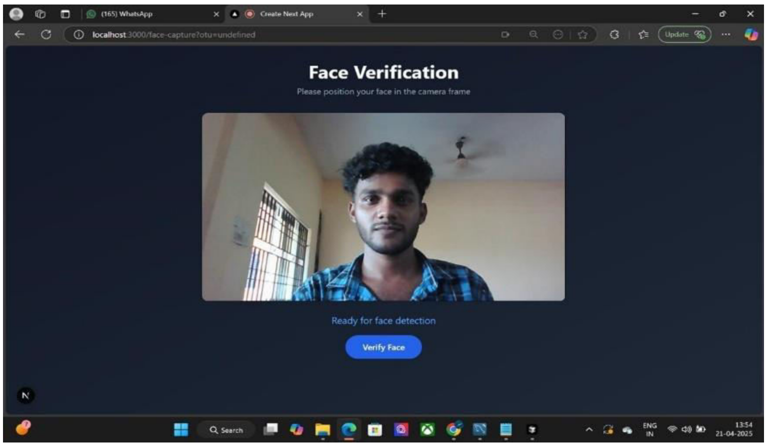
Address: 10 Church Street, Chennai

Security Status

Identity verified and secured

Fig. 5 OUT generation page

In Fig 5, The screen shows verified voter details including name, ID, contact, and address, confirming identity before voting. It provides the option to proceed with voting or return to authentication.



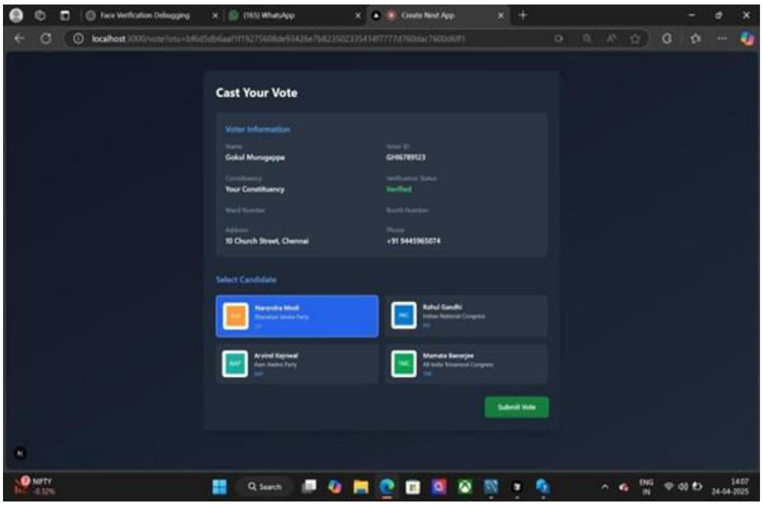
Face Verification

Please position your face in the camera frame

Ready for face detection

Fig. 6 Facial verification page

In Fig 6, The screen displays a face verification step, asking the user to align their face within the camera frame. It is ready for detection and prompts the user to click "Verify Face" to proceed.



Cast Your Vote

Voter Information

Name: Gokul Murugappa

Voter ID: GHI6789123

Constituency: Your Constituency

Verification Status: Verified

Ward Number

Booth Number

Address: 10 Church Street, Chennai

Phone: +91 9445965074

Select Candidate

- BJP Narendra Modi, Bharatiya Janata Party, BJP
- INC Rahul Gandhi, Indian National Congress, INC
- AAP Arvind Kejriwal, Aam Aadmi Party, AAP
- TMC Mamata Banerjee, All India Trinamool Congress, TMC

Fig. 7 Vote casting page

In Fig 7, This screen allows the user to cast their vote by selecting a candidate from a list. Voter details are shown for verification before submitting the vote.

VI. CONCLUSION

In conclusion, the proposed blockchain-based remote voting system effectively enhances electoral security, transparency, and accessibility by integrating advanced authentication mechanisms, encryption, and decentralized ledger technology. The incorporation of Aadhaar and Voter ID-based authentication, multi-factor biometric verification, and HMAC-SHA-256 encryption ensures robust voter identity validation and vote integrity. The use of Polygon blockchain for storing OTUs and recording votes guarantees immutability and traceability, while AI-powered real-time monitoring strengthens fraud detection. Moreover, Zero-Knowledge Proofs uphold voter privacy without compromising vote authenticity. By leveraging smart contracts for automated vote counting and auditability, this system minimizes human intervention, reducing the risk of manipulation. Overall, this secure, scalable, and efficient remote voting solution addresses key electoral challenges, paving the way for trustworthy and inclusive digital democracy.

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