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Research Article

Next-Generation National Voting Framework Using Aadhaar-Integrated Decentralized Blockchain and Analytics

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Abstract
This paper presents an innovative approach to digital elections through a decentralized blockchain-based voting platform, tightly integrated with Aadhaar verification. The model introduces a dual-layer voter authentication mechanism using Aadhaar-linked OTP and biometric data to guarantee security, voter legitimacy and tamper-proof operations. Ethereum smart contracts ensure real-time vote recording and transparent result computation. A pilot test of the proposed system is analysed and future scalability is assessed to demonstrate its feasibility for large-scale democratic processes in India.

Keywords: *Blockchain, Ethereum, e-Voting, Aadhaar, Biometric Authentication, OTP Verification, Smart Contracts, Digital Elections.*

1. Introduction
Conventional voting processes face criticism due to risks like manipulation, delayed outcomes and accessibility limitations. While Electronic Voting Machines (EVMs) help automate voting, they are not immune to centralized interference. This paper proposes a decentralized blockchain framework, combining Aadhaar-linked OTP and biometric verification, to deliver a transparent and secure voting solution for the Indian electorate.

2. Related Research
Previous studies have explored blockchain in electoral applications to enhance transparency and trust. Examples include Estonia's digital voting using national IDs and multiple Ethereum-based prototypes. However, these systems often fall short of incorporating a strong identity layer like Aadhaar for voter authentication.

3. System Architecture
The proposed system includes two roles: Voter and Admin. Voters interact with the system via secure web/mobile interfaces using MetaMask. Ethereum smart contracts control voter validation, candidate listing, voting access and real-time result updates. The backend ensures that each vote is unique and verifiable.

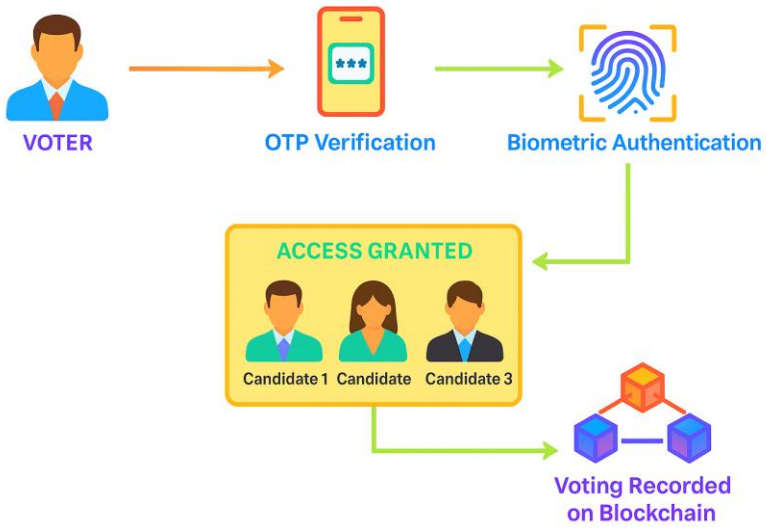

Fig 1: System architecture diagram (pictorial flow of Aadhaar + Blockchain voting process)

4. Voter Authentication Workflow

4.1 OTP Verification: Voters input their Aadhaar number and receive an OTP on their registered mobile number. This serves as the first authentication layer.

4.2 Biometric Confirmation: Upon OTP verification, the system prompts fingerprint or facial recognition to validate voter identity further.

4.3 Vote Authorization: Access to the vote-casting interface is granted only after successful completion of both steps, enforced via smart contracts.

5. Pilot Study and Results

A small-scale implementation with 25 verified users was carried out:

Results:

- **Total Votes:** 25
- **Winning Candidate:** AAA (XYZ Party) with 10 votes
- **Gender Distribution:** 72% Male, 28% Female
- **Voting Duration:** ~2 minutes 19 seconds

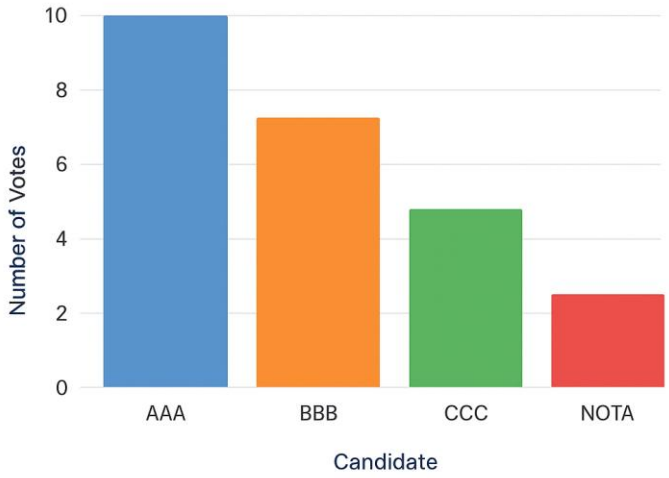

Fig 2: Candidate-wise Vote Distribution

The bar chart illustrates the number of votes secured by each candidate in the pilot study of the decentralized blockchain voting system.

Candidate-wise Votes:

AAA: 10
BBB: 8
CCC: 5
NOTA: 3

The system recorded each vote with a precise timestamp and ensured immutability and transparency.

6. Statistical Calculations and Analysis

6.1 Gender Participation Rate:

- Male Voters: 18/25 = 72%
- Female Voters: 7/25 = 28%

6.2 Candidate Vote Share:

- AAA: (10/25) x 100 = 40%
- BBB: (8/25) x 100 = 32%
- CCC: (5/25) x 100 = 20%
- NOTA: (3/25) x 100 = 12%

6.3 Mean and Standard Deviation of Votes:

- Mean (Average Votes per Candidate) = 25/4 = 6.25
- Standard Deviation:

Variance = $[(10-6.25)^2 + (8-6.25)^2 + (5-6.25)^2 + (3-6.25)^2]/4$

Variance = $[14.0625 + 3.0625 + 1.5625 + 10.5625]/4 = 7.3125$

Standard Deviation = $\sqrt{7.3125} \approx 2.70$

6.4 Voter Turnout Efficiency:

Assuming 30 registered voters, turnout = (25/30) x 100 = 83.33%

6.5 Average Time per Vote:

- Total time: 2 min 19 sec = 139 sec
- Average time per voter: 139/25 ≈ 5.56 sec

7. Security, Scalability and Future Projections Blockchain provides tamper-proof and auditable records. Aadhaar integration ensures legitimate voting. Smart contracts block duplicate entries. Ethereum supports low-latency processing, ideal for mass adoption.

Projected Growth (2030–2050):

- Voter base increase from 100M to 500M.
- Storage need from 500 GB to 2500 GB.
- Secure handling of national-level election data.

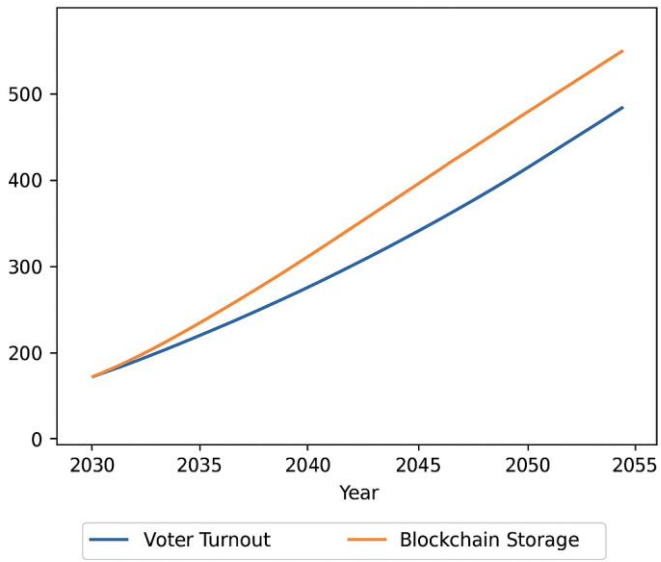

Fig 3: Future Scalability Projection

7.1 Future Use Cases:

- National Elections (Parliamentary, State Legislative Assemblies).
- Local Body Elections (Panchayat, Municipal Corporations).
- University and Institutional Elections.
- Private Organization Internal Elections.
- Shareholder Voting in Corporations.

7.2 Expected Scalability Calculations for National Elections:

- Total Registered Voters (India, Approx.): 950 million.
- Estimated Turnout (65%): 617.5 million voters.
- Expected Blockchain Transactions: 617.5 million.
- Estimated Blockchain Storage (approx. 250 bytes per vote):
  Total Storage = 617.5M x 250 bytes = ~154.375 GB.

Average Transaction Processing Time (with scaling solutions): < 3 seconds.

7.3 Potential Benefits:

- Savings of up to INR 25,000 crore in election expenses.
- Drastic reduction in fraud and recount incidents.
- Instant result declaration within minutes after voting closure.
- Global accessibility for NRIs.

8. Conclusion

The integration of Aadhaar authentication with decentralized blockchain technology creates a robust, secure and scalable solution for modern digital elections. Through dual-layer verification and smart contract execution, the system assures electoral integrity, efficiency and nationwide adaptability.

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