Online Voting System Using Blockchain

# Major Project Report

Submitted in partial fulfillment of the requirement of University of Mumbai For the Degree of

**(Computer Engineering)**

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Academic Year 2024-2025

**CERTIFICATE**

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# Project Report Approval

This Major Project Report – entitled “**Online Voting System Using Blockchain**” by following students is approved for the degree of **B.E. in "Computer Engineering"**.

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# Declaration

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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We take the privilege to express our sincere thanks to **Dr. L. K. Ragha** our Principal for providing the encouragement and much support throughout our work.

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# Abstract

The **Online Voting System Using Blockchain** project aims to revolutionize traditional voting systems, addressing prevalent issues like fraud, tampering, inefficiencies, and high operational costs. Traditional electoral processes, especially in large democracies like India, are resource-intensive and vulnerable to tampering. Blockchain, with its decentralized and immutable characteristics, offers a solution by securely recording votes in a tamper-proof manner. This system leverages **Ethereum blockchain** to ensure the integrity, security, and transparency of the voting process, allowing votes to be stored immutably and auditable for transparency.

One of the core challenges with blockchain-based systems is **scalability**. Blockchain transactions can be costly and time-consuming when applied to large-scale elections, such as those conducted in India. To mitigate this, the project adopts a **hybrid approach**, utilizing **Firebase** as a **secondary database** to manage non-sensitive data like voter profiles, logs, and election metadata. This off-chain storage reduces the transaction load on the blockchain, enabling faster performance and lower operational costs, while the blockchain itself securely handles the critical aspects of vote recording and result declaration.

The system also incorporates **multi-factor authentication (MFA)** and **biometric verification**, ensuring that only authorized voters can access the platform. **MFA**, combined with **biometric data** (fingerprint or facial recognition), adds an additional layer of security, guaranteeing the legitimacy of the voter and protecting the voting process from unauthorized access. Once authenticated, voters can securely cast their votes through the mobile app, and their votes are immediately recorded on the blockchain.

The **real-time result visualization** feature is another key component of the system. As votes are recorded on the blockchain, results are processed and displayed in real-time, providing an immediate and transparent overview of the election's progress. This feature supports region-wise classification and detailed result breakdowns for elections ranging from **Gram Panchayat** to **Lok Sabha**, ensuring that voters and election officials have full transparency throughout the election cycle. The blockchain guarantees that votes cannot be modified once cast, eliminating any risk of post-election tampering or manipulation.

To ensure voter privacy and anonymity, the system isolates sensitive voting data on the blockchain, while Firebase handles metadata like whether a voter has participated. This separation ensures that voter data is never exposed, yet it allows election officials to verify voter participation without revealing sensitive information.

The project successfully demonstrates a scalable, cost-effective, and **secure alternative to traditional voting systems**. By eliminating the need for extensive manpower and reducing reliance on physical infrastructure, such as Electronic Voting Machines (EVMs), the blockchain-based system offers a modernized approach to conducting elections, with a focus on security, transparency, and efficiency. Its real-time results and auditability enhance voter trust, making the system particularly suitable for large-scale elections in India and globally.

The proposed system ensures that elections are **tamper-proof**, **transparent**, and **cost-efficient**, offering a blueprint for modernizing the electoral process through blockchain technology.

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| **Sr. No.** | **Abbreviations** | **Full Form** |
| 1 | IT | Information Technology |
| 2 | SDLC | Software Development Life Cycle |
| 3 | UI | User Interface |
| 4 | UX | User Experience |
| 5 | GB | Giga Byte |
| 6 | RAM | Random Access Memory |
| 7 | HTML | Hyper Text Markup Language |
| 8 | CSS | Cascading Style Sheet |
| 9 | JS | JavaScript |
| 10 | MB | Mega Byte |
| 11 | GHz | Giga Hertz |
| 12 | OS | Operating System |
| 13 | DFD | Data Flow Diagram |
| 14 | ER | Entity Relationship |
| 15 | RMMM | Risk Mitigation Monitoring and Management |

**Chapter 1**

**Introduction**

### Introduction:

The electoral process is a cornerstone of democracy, providing citizens the means to participate in governance. In large democratic countries like India, where elections are held on a vast scale, traditional voting methods, such as paper ballots and **Electronic Voting Machines (EVMs)**, face significant challenges. These challenges include **voter fraud**, **vote tampering**, **inefficiency**, and **high operational costs**. The centralized nature of these systems makes them vulnerable to manipulation, raising concerns about the integrity of election results and eroding public trust in the electoral process.

In recent years, **blockchain technology** has emerged as a robust solution to these problems. Blockchain's **decentralized, immutable, and transparent** nature offers the potential to revolutionize electoral systems by providing a secure, efficient, and tamper-proof method of recording votes. By leveraging blockchain, each vote can be stored immutably on a decentralized ledger, ensuring that once a vote is cast, it cannot be altered or deleted. This enhances voter confidence and eliminates the risks associated with traditional systems. Moreover, blockchain’s ability to automate processes through **smart contracts** significantly reduces the need for human intervention, minimizing errors and ensuring timely vote counting and result declaration.

This project aims to design and implement a **Blockchain-Based Online Voting System** that integrates the security of blockchain with the accessibility and ease of a mobile voting application. The system addresses the scalability issues of blockchain by incorporating a **secondary database (Firebase)** to manage non-sensitive data, such as voter profiles and election logs, optimizing the system's performance for large-scale elections. The project also prioritizes **security and privacy**, ensuring that voters can cast their votes securely and anonymously while election officials can audit results transparently.

Through this system, the project seeks to modernize the electoral process, providing a **secure**, **cost-effective**, and **transparent** alternative to traditional voting methods. This is particularly relevant in the context of India, where elections involve millions of voters across diverse regions and scales, from **Gram Panchayat** to **Lok Sabha** elections. The proposed system ensures that the integrity of the voting process is maintained while significantly reducing the resources, time, and costs required to conduct elections.

**1.2 Organization of the Report**

This report is systematically organized into several key chapters, each contributing to a comprehensive understanding of the **Blockchain-Based Online Voting System**. The structure facilitates a logical flow of information, guiding the reader through the project’s objectives, methodologies, and findings.

1. **Introduction**: The opening chapter outlines the motivation behind the project, detailing the challenges posed by traditional voting systems, such as security vulnerabilities and inefficiencies. It introduces the advantages of a blockchain-based approach, emphasizing how this technology can enhance the electoral process.
2. **Problem Statement**: This section identifies and elaborates on the limitations of existing electoral systems, including issues related to vote tampering, fraud, and high operational costs. It articulates the core objectives of the proposed system, establishing a clear framework for addressing these challenges.
3. **Literature Review**: A comprehensive review of previous works related to traditional and blockchain-based voting systems is presented in this chapter. It highlights the strengths and weaknesses of existing approaches, providing a foundation for the development of the proposed solution.
4. **Software Requirements Specification (SRS)**: This chapter outlines the detailed requirements for the system, covering external interfaces, functional, performance, and security aspects. It ensures that all necessary criteria are established for the successful implementation of the voting system.
5. **Design and Architecture**: A breakdown of the system’s architecture is provided, including detailed diagrams illustrating blockchain integration, backend architecture, and database systems. This chapter presents the technical design decisions that underpin the project.
6. **Methodology**: The methodology section describes the tools, platforms, and development processes employed in the implementation of the system. It outlines the steps taken to ensure that the system is developed efficiently and effectively.
7. **Implementation**: This chapter covers the practical implementation of the voting system, detailing the development of smart contracts, the Android/Flutter application, and the integration of Firebase as a secondary database.
8. **Testing and Results**: A thorough account of the testing processes undertaken is provided, including functional and performance evaluations. This chapter presents the results of the testing, accompanied by analysis and discussion of their implications.
9. **Conclusion and Future Scope**: The final chapter summarizes the project’s key findings, reinforcing the significance of the proposed system. It also discusses potential future improvements and enhancements that could further optimize the voting platform.
10. **References**: The report concludes with a comprehensive list of all academic and technical sources referenced throughout the project, ensuring proper attribution and facilitating further research.

This structured approach ensures that the report presents a coherent narrative, guiding readers through the complexities of developing a blockchain-based online voting system. Each section builds upon the previous one, culminating in a comprehensive understanding of the project’s objectives, methodologies, and outcomes.

# Chapter 2

# Literature Survey

### Problem statement

Elections are the foundation of a democratic system, ensuring that citizens have the right to choose their representatives through a free and fair process. In a country as vast as India, where millions of voters participate in elections at various levels (from **Gram Panchayat** to **Lok Sabha**), traditional voting methods face significant challenges. These challenges include **security vulnerabilities**, **vote tampering**, **fraud**, and **inefficiencies** that can compromise the integrity of the electoral process.

Traditional voting systems, including **paper ballots** and **Electronic Voting Machines (EVMs)**, are susceptible to multiple forms of manipulation and are heavily reliant on manual processes. The centralized nature of these systems increases the risks of **data breaches** and **tampering**, with possibilities of unauthorized access, hacking, or altering vote counts. Moreover, the **centralized databases** used for storing election data are vulnerable to cyberattacks, which can lead to **data manipulation** or loss. This not only compromises the accuracy of election results but also damages public trust in the entire democratic process.

Another major concern is the **scalability** and **cost** associated with conducting elections in a country as populous as India. Managing millions of voters across geographically diverse and socially distinct regions is a highly resource-intensive process, requiring significant manpower, infrastructure, and finances. Additionally, traditional systems often experience **delays in result declaration**, with the process of counting votes and verifying results being slow and prone to human error.

The need for a **secure**, **transparent**, and **efficient** solution is paramount, particularly in the digital age, where there is an increasing demand for online and mobile-based services. However, online voting systems have their own challenges, primarily related to **security** and **voter privacy**. Implementing a decentralized solution like **blockchain technology** offers the potential to mitigate these issues by ensuring that votes are securely recorded in an immutable, tamper-proof ledger, without the need for a centralized authority.

The current problem therefore lies in addressing the following key issues with traditional voting systems:

1. **Voter fraud and tampering** due to centralized databases and manual handling.
2. **Inefficiency and high operational costs** of large-scale elections.
3. **Lack of transparency** and **delays** in result declaration.
4. **Voter privacy** and **data security concerns** in online voting systems.
5. **Scalability** issues that make existing systems unsuitable for large, diverse populations like India.

To resolve these issues, there is a clear need for a **Blockchain-Based Online Voting System** that ensures **vote integrity**, **security**, **privacy**, and **efficiency**, particularly for large-scale elections.

### 2.2 Existing System Survey:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Title | Publish & Year | Authors | Summary | Research Gap |
| Secure Electronic Voting System using Blockchain Technology | International Journal of Smart Home, 2020 | D.Dwijesh Kumar, D.V. Chandini, Dinesh Reddy |  |  |
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### Objectives

The primary objective of this project is to design and implement a **Blockchain-Based Online Voting System** that addresses the limitations and challenges of traditional voting systems, ensuring that the electoral process is secure, transparent, and scalable. The key objectives are as follows:

1. **Secure Vote Storage Using Blockchain**:  
   To leverage **Ethereum blockchain** technology to securely record votes in an immutable and decentralized manner. The blockchain will ensure that once a vote is cast, it cannot be tampered with or altered. By decentralizing vote storage, the system eliminates the vulnerabilities of a centralized database and ensures that votes are permanently secured in a tamper-proof ledger.
2. **Voter Authentication and Privacy**:  
   To implement **Multi-Factor Authentication (MFA)** and **biometric verification** to ensure that only authorized voters can access the voting system. This objective is critical for ensuring the legitimacy of voters and preventing unauthorized access. At the same time, the system must ensure **voter privacy** by isolating sensitive data and providing **anonymity** during vote casting.
3. **Smart Contract Integration for Vote Validation and Counting**:  
   To develop **smart contracts** that automate the vote validation, counting, and result declaration processes. The smart contracts, deployed on the Ethereum blockchain, will ensure that each voter can only vote once and that votes are counted transparently and automatically. This will reduce the reliance on human intervention and minimize the chances of errors or manipulation during vote counting.
4. **Real-Time Result Visualization**:  
   To provide **real-time election results** that can be viewed by voters and election officials through a mobile app. The system will display election results immediately as votes are recorded on the blockchain, offering both list and graphical views. This objective is essential for enhancing the **transparency** and **efficiency** of the election process.
5. **Scalability and Cost-Effectiveness**:  
   To integrate a **secondary database (Firebase)** to handle non-sensitive data such as voter profiles, logs, and election metadata. This will reduce the load on the blockchain and ensure that the system can scale to handle large numbers of voters during national or regional elections. The hybrid approach will also reduce operational costs associated with blockchain transactions, making the system more cost-effective for large-scale elections.
6. **Comprehensive Election Coverage**:  
   To support various levels of elections, including **Gram Panchayat**, **Vidhan Sabha**, and **Lok Sabha** elections. The system will allow voters to participate in elections based on their geographic location, offering comprehensive coverage of the entire electoral process.
7. **Transparency and Audibility**:  
   To ensure that the system provides full **transparency** in the voting process by maintaining an immutable record of all transactions (votes) on the blockchain. The system must allow for auditability by election officials without compromising voter privacy. This objective is critical to restoring public trust in the electoral process and ensuring that the system remains credible and trustworthy.
8. **Future Scalability and Enhancements**:  
   To design the system in such a way that it can be further enhanced in the future by incorporating **Layer-2 scaling solutions**, such as rollups or sidechains, and potentially integrating **Artificial Intelligence (AI)** for analyzing voter patterns and behaviors. This objective ensures that the system is not only suitable for current use cases but can also adapt to future technological advancements and electoral needs.

### Scope of the project:

The **Blockchain-Based Online Voting System** developed in this project is aimed at addressing the fundamental challenges of traditional voting methods, specifically in the context of large-scale elections, such as those held in India. The scope of this project encompasses various technical, operational, and security aspects to ensure a modern, scalable, and transparent electoral process. Below is a detailed outline of the scope:

**1. Security and Immutability**

The system leverages the **Ethereum blockchain** to store votes in an immutable manner. Each vote, once cast, is permanently recorded on the decentralized blockchain, preventing any possibility of tampering, modification, or deletion. The blockchain's decentralized nature ensures that no single entity has control over the voting data, eliminating the risks associated with centralized databases. This guarantees **vote integrity** and boosts voter confidence in the system. By recording votes on a public, decentralized ledger, the system provides **transparency** while preserving the **privacy** of voters.

**2. Smart Contract Integration**

The system utilizes **smart contracts** written in **Solidity** to automate the key voting processes. Smart contracts serve to:

* Validate votes and ensure that each voter can only cast one vote.
* Count the votes in real-time.
* Automatically declare election results once voting concludes. These contracts eliminate the need for human intervention in vote counting, reducing the chances of human error and accelerating the result declaration process. The use of smart contracts ensures that the entire process is executed **fairly, transparently, and securely**, with predefined rules that cannot be altered once deployed.

**3. Mobile Application Interface**

The system is designed as a **mobile application** using **Flutter** for cross-platform support on both **Android and iOS** devices. The app provides an intuitive user interface (UI) that allows voters to:

* **Register** securely using their voter ID.
* **Authenticate** using **multi-factor authentication (MFA)**, which includes biometric verification (e.g., fingerprint, facial recognition).
* **Cast votes** electronically in a secure environment.
* **View real-time results** of the election in a variety of formats, such as graphical visualizations or detailed lists. The mobile interface simplifies the voting process for citizens, providing easy access to voting without the need for physical infrastructure, and supports scalability for large-scale elections.

**4. Secondary Database (Firebase) Integration**

To overcome the **scalability limitations** inherent in blockchain technology, the project incorporates a **secondary off-chain database** using **Firebase**. While the blockchain securely stores votes, Firebase is used to store **non-sensitive data** such as voter profiles, logs, and election metadata. This reduces the computational and financial burden on the blockchain, making the system **cost-effective** and scalable for large elections. By separating critical and non-critical data, the system ensures **optimal performance** during high voter turnout.

**5. Real-Time Results and Transparency**

The system ensures that election results are calculated and displayed in **real-time**. Voters and election officials can view up-to-the-minute results through the mobile application, enhancing the **transparency** of the election process. Additionally, the system provides region-wise classifications and detailed breakdowns, allowing for a clear and organized presentation of election results for multiple levels, including **Gram Panchayat**, **Vidhan Sabha**, and **Lok Sabha** elections. The transparency afforded by blockchain ensures that the election process can be **audited** at any time, with immutable records stored on the blockchain.

**6. Scalability and Performance**

The system is designed to be **scalable** and capable of handling **millions of voters** during large elections, such as national or state-level elections in India. By combining the **Ethereum blockchain** for critical vote storage and **Firebase** for metadata management, the system optimizes its performance and ensures that it can handle high volumes of transactions without compromising on speed or security. Future enhancements, such as **Layer-2 scaling solutions** or the integration of **Artificial Intelligence (AI)** for analyzing voter patterns, could further improve scalability and functionality.

**7. Comprehensive Election Classification and Coverage**

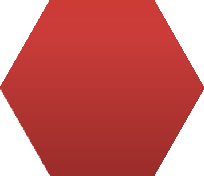
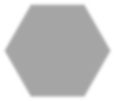
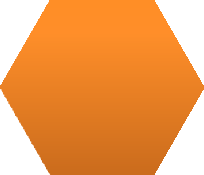
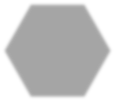
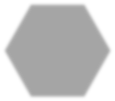
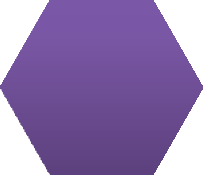
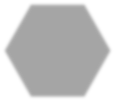
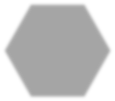
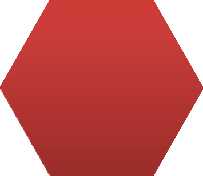
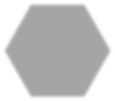
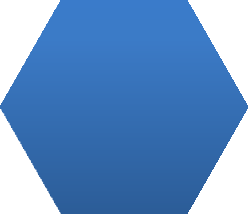
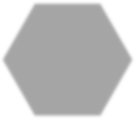
The system supports all types of elections conducted in India, from **local** to **national** levels. It is designed to handle various electoral categories, including:

* **Gram Panchayat**
* **Vidhan Sabha**
* **Lok Sabha** The system provides full coverage of the electoral hierarchy, ensuring that voters are presented with the appropriate election options based on their region. This classification system is crucial in ensuring that elections are well-organized, and that the correct data is presented to voters based on their geographic location.

# Chapter 3

**Software Requirements Specification**

* 1. **Software Model**



Analyze

Maintenance

Plan

Agile

Development

Deploy

Design

Develop

Fig 3.1 Agile Model

The following are some particular advantages of utilizing the Agile SDLC Model:

* + - **Reduced risk:** By providing functioning software early and frequently, the Agile SDLC Model helps to decrease risk. Users and stakeholders may submit input and detect possible issues early on.
    - **Increased customer satisfaction:** Agile teams collaborate closely with users throughout the development process, ensuring that the solution satisfies their requirements. This increases consumer satisfaction.
    - **Product quality** is improved because the Agile SDLC Model stresses continual improvement. This contributes to the product being of the greatest possible quality.

**3.1.1 Phases of Software Model**

1. **Planning:**

* During the planning stage, the team establishes the goals, scope, and first backlog of products.
* Establishing an Agile team, coming up with a product vision, and planning a project schedule are important duties.

1. **Requirements Analysis:**

* Agile development frequently begins with a discovery phase in which stakeholders are closely partnered with to identify needs and collect high-level requirements.
* In this phase you can develop a product backlog with priorities.

1. **Design:**

* Work on design and prototyping is done concurrently with development during each iteration.
* This comprises designing the information architecture, UI/UX, and wireframes.

1. **Implementation:**

* In this phase actual coding is done based on the technology stack.
* The tasks assigned to developers during the iteration include putting the features and user stories into practice.

1. **Testing:**

* Continuous testing is done by agile teams all along the development process.
* User acceptability testing, integration testing, and unit testing are all included in this.

1. **Deployment:**

* With agile, deployment may be done incrementally. As soon as new features are available, you can release them into production.
* Regular releases guarantee that users receive valuable features frequently and early.

1. **Maintenance and Support:**

* Post-release, the team continues to provide support and maintenance, addressing any issues, bugs, or required updates.
* This phase runs concurrently with ongoing development work in subsequent iterations.

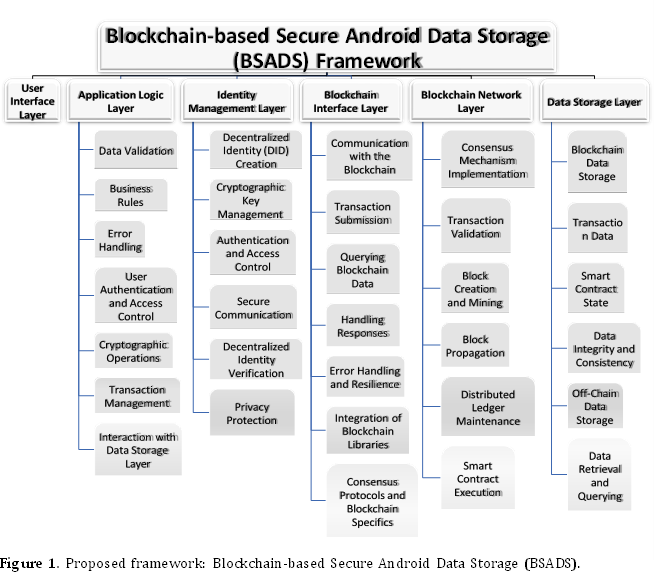
## Proposed System

* + 1. **Technical Design**

1. **Data Flow and System Components**

A high-level model of the use of a blockchain-based system for Android data storage is suggested. We propose a six-layer framework called Blockchain-based Secure Android Data Storage (BSADS) that could help developers build a secure Android app with blockchain data storage capabilities (See Figure 1) [7].

The proposed blockchain-based voting system integrates multiple components into a secure and scalable architecture, designed to address the challenges of large-scale elections. The data flow between these components is structured as follows:



* + 1. **User Interface (UI) Layer**:
       1. This layer acts as the interaction point between voters and the system. It allows voters to register, authenticate, and cast votes via a user-friendly mobile application interface. This layer is designed for accessibility and usability, ensuring voters can seamlessly navigate the voting process.
    2. **Application Logic Layer**:
       1. This layer manages the core functionality and business logic of the voting system. It validates user inputs, processes transactions, and manages communication between the UI and backend layers. It is responsible for ensuring the secure transmission of requests and responses to and from the blockchain and the off- chain database.
    3. **Identity Management Layer**:
       1. This layer handles decentralized identity (DID) creation and cryptographic key management. It ensures that voter identities are securely stored and verified during interactions with the system. By managing authentication and access control, this layer provides robust security for user data and interactions.
    4. **Blockchain Interface Layer**:
       1. This layer manages all interactions with the blockchain, facilitating the submission of votes, querying data, and handling transaction responses. It ensures
       2. that all communication between the mobile app and the Ethereum blockchain is secure and reliable, handling the complexity of interacting with a decentralized network.
    5. **Blockchain Network Layer**:
       1. This layer implements the Ethereum blockchain’s consensus mechanism (Proof of Stake), ensuring that each vote is validated, added to the blockchain, and securely stored. It is responsible for transaction validation, block creation, and maintaining the decentralized ledger.
    6. **Data Storage Layer**:
       1. This layer separates data storage between the blockchain and off-chain databases. Votes and critical election data are stored on-chain to ensure immutability and security. Non-sensitive metadata, such as voter profiles and logs, is stored off- chain using Firebase or MongoDB, optimizing performance and reducing the load on the blockchain.

**2, Scalability and Security**

The proposed system is designed to address the scalability challenges typically encountered in large-scale elections. By employing a hybrid solution that combines blockchain technology with off-chain storage, the system is capable of handling millions of users efficiently, without compromising security or performance.

1. **Blockchain for Votes:**

Votes are stored on the Ethereum blockchain, ensuring immutability and security. This prevents tampering or unauthorized access to the stored data.

1. **Off-chain Databases for Metadata:**

Non-sensitive information, such as voter profiles and system logs, is stored in off- chain databases like Firebase or MongoDB. This approach reduces the transaction load on the blockchain, ensuring faster performance and lower costs during peak voting times.

**3, System Components and Integration**

The system integrates several core components to achieve scalability and security:

* + 1. **Mobile App (Flutter/Android):**

Provides the front-end interface through which voters register, authenticate, and cast their votes.

* + 1. **Backend (Node.js, Web3.js):**

Manages API requests and facilitates seamless communication between the mobile app and the blockchain.

**Iii. Blockchain (Ethereum):**

Serves as the immutable and decentralized platform where votes are securely recorded.

**Iv. Off-Chain Database (Firebase/MongoDB):**

Stores non-vote-related data, optimizing system performance and enabling faster response times.

These components work together through a series of secure API calls, ensuring that data flows seamlessly between the user interface, backend systems, and the blockchain network.

3,2,2 **System Architecture**

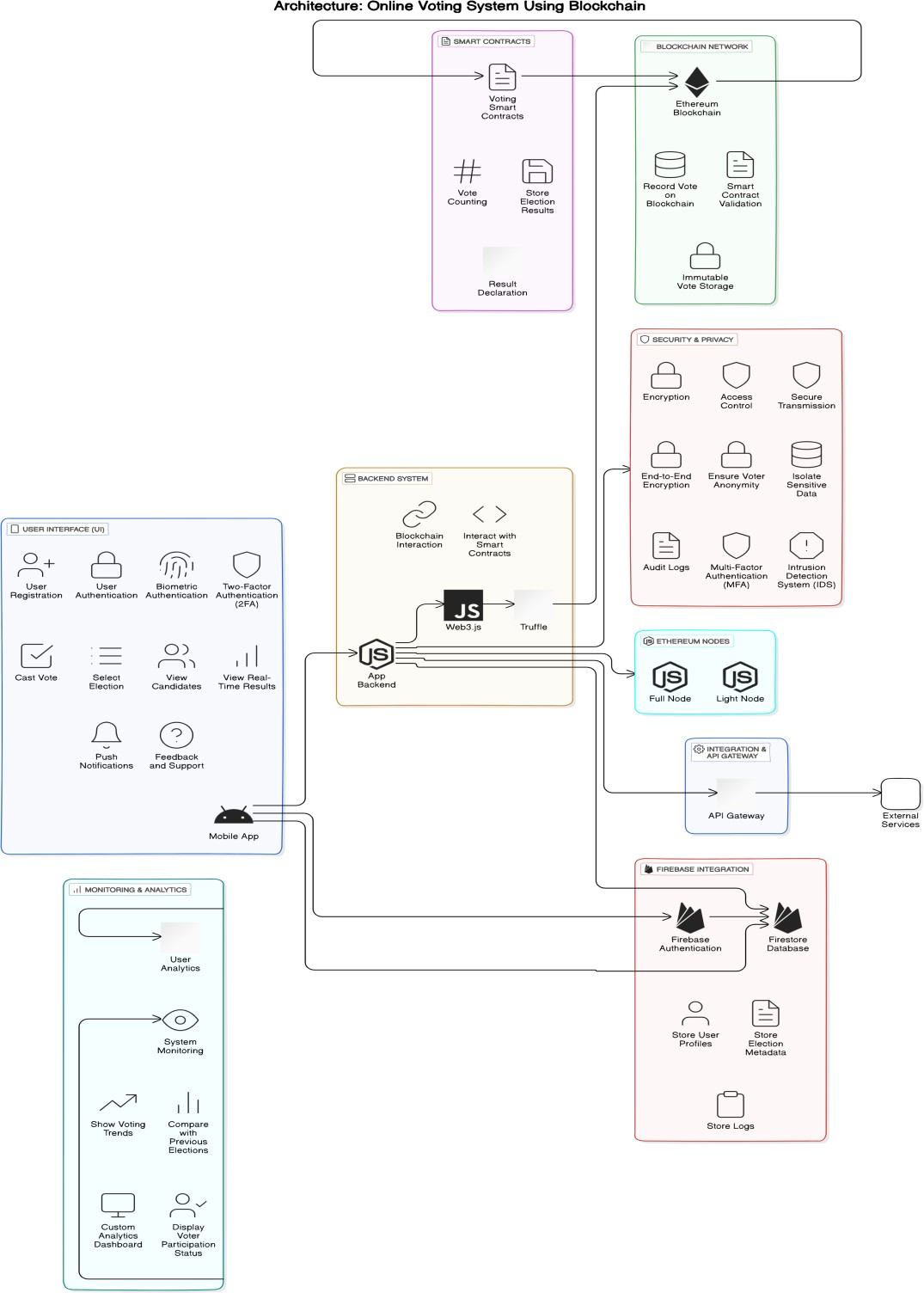


Figure 2. Architecture of the system

* + - 1. **The proposed system consists of key components:**
      2. **Voting Process**
      3. **Key Features**

**3.2.3 Technical Components:**

1. **ser Interface (UI)**
2. **Backend System (Node.js)**
3. **Blockchain Integration (Ethereum)**
4. **Firebase for Metadata Management**

This solution offers a secure, decentralized, and scalable voting system designed to address the current inefficiencies in India's traditional electoral processes. By integrating blockchain for vote security and Secondary database for managing non-sensitive metadata, the system is designed to handle large-scale elections efficiently, reducing costs and ensuring voter trust.

This technical design ensures a **secure, scalable, and efficient voting system** capable of handling large-scale elections, such as those in India. The hybrid architecture optimizes the strengths of blockchain technology while leveraging Firebase to reduce costs and enhance performance.

**3.3** **Software & Hardware** **Requirements**

**3.3.1 External Interface Requirements**

The **External Interface Requirements** detail how the system interacts with users and other systems, ensuring seamless integration and user experience.

1. **User Interfaces**

The system must provide an intuitive and user-friendly interface for various stakeholders, including voters, candidates, and election officials. The key features of the User Interface (UI) include:

* **Voter Registration Interface**: A straightforward registration form allowing users to input identification details and biometric data. This interface will guide users through the registration process, ensuring clarity and ease of use.
* **Authentication Interface**: A secure login interface that facilitates multi-factor authentication (MFA), requiring users to provide passwords and one-time passwords (OTPs) for enhanced security.
* **Voting Interface**: A clear and accessible interface for casting votes. Voters can view candidates and make selections easily, with real-time feedback to confirm their vote has been recorded.
* **Results Interface**: A dashboard displaying real-time election results, featuring both list and graphical formats for easy comprehension. This interface will allow users to filter results based on various criteria, such as region and election type.

1. **Software Interfaces**

The system will interact with several external software components to function effectively:

* **Blockchain Interface**: The application must integrate with the **Ethereum blockchain** to securely store votes and execute smart contracts for vote validation and result declaration. This interface will ensure seamless communication between the application and the blockchain network.
* **Firebase Database**: The system will connect to Firebase for managing non-sensitive data such as user profiles and election metadata. The integration will facilitate efficient data retrieval and storage, supporting the application's overall performance.
* **APIs for Authentication**: The application will utilize third-party APIs for additional security measures, such as SMS gateways for OTP generation and email services for notifications and confirmations.

1. **Hardware Interfaces**

The system is designed to operate on various hardware platforms, ensuring accessibility for all users:

* **Mobile Devices**: The application will be compatible with smartphones and tablets, utilizing touch-screen functionality for ease of use. It will support both **Android** and **iOS** operating systems.
* **Desktop and Laptops**: The web interface will be optimized for various browsers, ensuring that users can access the voting system from desktops and laptops.
* **Biometric Scanners**: If implemented, the system will interface with biometric hardware for user authentication, enabling secure and swift voter verification.

**3.3.2 Functional Requirements**

The **Functional Requirements** specify the actions the system must be able to perform.

**1. Give Input**

* **User Registration**: The system must allow users to register securely by entering their unique identification details and biometric data. The application will validate the data before generating a unique voter ID.
* **Vote Casting**: Once authenticated, voters must be able to select their preferred candidate(s) and submit their vote through the voting interface. The system will capture and securely transmit this input to the blockchain.
  + - 1. **Submit Input**
* **Vote Submission Confirmation**: Upon submitting their vote, users will receive a confirmation notification indicating that their vote has been successfully recorded. This feature enhances user confidence in the system's functionality.
* **Feedback Mechanism**: Users should be able to provide feedback or report issues regarding the voting process. This input will be valuable for future enhancements and user experience improvements.

**3.3.3 Performance Requirements**

The **Performance Requirements** outline the expected operational capabilities of the system under various conditions.

* 1. **Response Time**
* The system must provide a response time of less than **2 seconds** for user interactions, including registration, authentication, vote casting, and results retrieval.
  1. **Scalability**
* The architecture must support scalability to handle **millions of concurrent users** during peak voting periods, ensuring that the system remains responsive and efficient.
  1. **Prediction Throughput**
* The system should be capable of processing and recording at least **1,000 votes per second** to accommodate large-scale elections without delays.
  1. **Security Performance**
* The system must maintain high security performance levels, ensuring that no security breaches occur during any voting operations, even under heavy load.
  1. **Data Processing Speed**
* The application should be able to process data inputs (e.g., user registrations and vote submissions) in less than **1 second** to enhance user experience and reduce wait times.

**3.3.4 Security Requirements**

The **Security Requirements** detail the necessary measures to protect user data and maintain the integrity of the voting process.

1. **Data Encryption**

* All data transmitted between the mobile application, backend, and blockchain must be encrypted using **end-to-end encryption protocols** (e.g., **AES-256**) to ensure the confidentiality and integrity of sensitive information.

1. **Access Control**

* The system must implement role-based access control (RBAC), ensuring that only authorized personnel (e.g., election officials) can access sensitive administrative features while keeping voter data secure and private.

1. **Authentication and Authorization**

* The application must utilize **multi-factor authentication (MFA)** to verify voter identities. This will include password protection, OTPs, and biometric verification to enhance security and prevent unauthorized access.

1. **Data Integrity**

* The system must ensure data integrity through the use of blockchain technology, where all transactions (votes) are recorded in an immutable ledger. Additionally, the application should maintain audit logs for all critical operations, allowing election officials to verify the integrity of the voting process without compromising voter privacy.

**3.4 Feasibility Analysis**

**3.4.1 Technical Feasibility**

1. **Blockchain for Vote Storage**: Ethereum or a similar blockchain network ensures secure, immutable, and tamper-proof vote storage. Smart contracts enable vote counting and ensure that no duplicate voting occurs.
2. **Firebase for Metadata**: Storing non-sensitive data such as voter logs and metadata in Firebase provides a cost-effective and efficient solution for off-chain operations, reducing blockchain transaction costs.
3. **User-Friendly Authentication**: Multi-factor authentication (MFA) with biometric verification provides a secure and easy way for voters to register and authenticate.

**3.4.2 Financial Feasibility**

1. **Cost of Blockchain Transactions**: Public blockchains like Ethereum have transaction costs, but this can be minimized by using Layer 2 scaling solutions or consortium blockchains. Additionally, operations such as vote recording are optimized to avoid unnecessary costs.
2. **Firebase Usage Costs**: Firebase is utilized for handling non-voting-related metadata and logs, which reduces the need for on-chain storage, keeping costs low.

**3.4.3 Operational Feasibility**

1. **Ease of Use**: The mobile app is designed for ease of use, with a straightforward interface for voters to register, select elections, and cast votes. Multi-factor authentication ensures that even non-technical users can participate securely.
2. **Handling Peak Voting Periods**: The system is scalable to handle a large number of users during peak voting times, ensuring that even national elections can be conducted smoothly.

# Design

## 3.5.1 Data Flow Diagram (DFD)

Fig 5.1.1 DFD Level-0

Fig 5.1.2 DFD Level-1

## Use Case Diagram

Fig 5.1.3 DFD Level-2

Fig 5.2 Use Case

## Sequence Diagram

Fig 5.3 Sequence Diagram

The above figure shows the sequence of the system.

## Gantt Chart

Fig 5.4 Gantt Chart

3.6 RMMM Plan

**RMMM Plan (Risk Mitigation, Monitoring, and Management)**

**Table: Risk Categories**

| **Risk ID** | **Risk Category** | **Probability** | **Impact** | **Description** | **Mitigation Plan** | **Monitoring Strategy** | **Management Strategy** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| RMMM1 | **Scalability** | 60% | High | Ethereum’s transaction throughput may cause delays, especially in large elections. | Implement transaction batching and use a private blockchain for low-cost, high-speed transactions. | Monitor transaction processing times and user load during peak voting periods. | Scale the infrastructure dynamically during high traffic voting periods. |
| RMMM2 | **Security** | 50% | High | DDoS attacks could affect the backend or blockchain interaction, causing system downtime. | Strengthen backend security with rate limiting, firewalls, and distributed denial-of-service (DDoS) prevention mechanisms. | Continuous monitoring for unusual traffic patterns. | Activate fallback systems and reroute traffic to unaffected nodes. |
| RMMM3 | **Privacy** | 30% | High | Sensitive voter data may be exposed due to insufficient encryption or data management practices. | Implement end-to-end encryption for all sensitive data transfers and storage. | Regular audits of encryption protocols and data flow paths. | Ensure legal compliance with privacy regulations; isolate sensitive data in blockchain. |
| RMMM4 | **System Downtime** | 20% | Moderate | Unexpected system downtime may cause disruption in elections. | Deploy backup servers and failover systems to ensure high availability. | Track system performance, uptime, and downtime metrics. | Have emergency support available for immediate issue resolution. |
| RMMM5 | **Integration Failures** | 40% | Moderate | Integration between the mobile app, backend, and blockchain may face challenges. | Implement continuous integration testing for app-backend-blockchain workflows. | Monitor API responses, transaction failures, and timeout issues. | Develop fallback logic to handle temporary disconnections gracefully. |

**Chapter: 4**

**Methodology**

Fig 6.1 Overview of the proposed system

This chapter outlines the methodology adopted in the development of the **Blockchain-Based Online Voting System**. The methodology encompasses the tools and technologies used, the process flow of the system, and the steps taken to ensure security, performance, and user experience.

* 1. **Blockchain Integration**

**4.1.1 Development Environment:**

* + - 1. **Ganache/Truffle:**

During the development phase, Ganache and Truffle will be used to simulate a local Ethereum blockchain environment. This will enable testing of smart contracts and voting transactions in a controlled setup before deploying to the live Ethereum network.

* + - 1. **Web3.js and Node.js:**

These tools will facilitate communication between the mobile app, backend, and blockchain. Web3.js will handle smart contract interactions from the frontend, while Node.js will manage API requests and backend operations.

**4.1.2 Voting Process:**

* + - 1. **Vote Transactions:**

Once a voter casts a vote, the mobile app sends the transaction to the backend. The backend then interacts with the Ethereum blockchain using smart contracts to record each vote as a transaction.

* + - 1. **Vote Validation:**

Smart contracts written in Solidity will validate each vote, ensuring authenticity and preventing multiple votes from the same voter.

* + - 1. **Result Publication:**

As soon as voting is concluded, smart contracts automatically count votes and publish results in real-time on the blockchain, providing transparency and immutability.

* 1. **Security and Privacy**

**4.2.1 Multi-factor Authentication (MFA):**

The system will incorporate MFA, including biometric or OTP-based authentication, to ensure that only legitimate users can vote.

* + 1. **End-to-End Encryption:**

All data transmitted between the mobile app, backend, and blockchain is encrypted to protect user privacy and system security.

* + 1. **Anonymity and Transparency:**
  1. **Blockchain Ledger:**

While the blockchain maintains a transparent ledger of transactions (votes), the anonymity of each vote is preserved, ensuring voter privacy.

* 1. **Smart Contracts for Security:**

Smart contracts ensure that each vote is unique, correctly counted, and tamper-proof.

* 1. **Performance Optimization**

**4.3.1 Data Segmentation:**

* 1. **Blockchain for Votes:**

Only sensitive data, such as votes and election results, are stored on the Ethereum blockchain to leverage its immutability and security features.

* 1. **Secondary Database for Non-sensitive Data:**

Non-vote-related data, such as voter profiles, election metadata, and user activity logs, will be stored in secondary database. This approach reduces the load on the blockchain and ensures faster system performance, particularly during peak voting times.

* + 1. **Cost-Effectiveness:**
    2. **Transaction Batching:**

To minimize gas fees and improve performance, vote transactions are batched together during high voting volumes.

**2. Optimized Scalability:**

By offloading non-critical data to secondary database, the system remains scalable and cost-effective during large-scale elections, such as national elections.

* 1. **Process Breakdown**

**4.4.1 Voter Registration:**

* + - * 1. **User Flow:**

Users register through the mobile app by providing identification details, which are verified through MFA. Once verified, the system generates a unique voter ID, which is stored on the blockchain for future voting authentication.

* + 1. **Vote Casting:**
  1. **User Flow:**

After selecting a candidate from the list of eligible elections, the vote is securely transmitted to the Ethereum blockchain via the backend. A confirmation message is displayed in the app once the vote is successfully recorded on the blockchain.

**2. Transaction Validation:**

Smart contracts verify the legitimacy of the vote and ensure that no voter casts more than one vote.

* + 1. **Data Handling and Storage:**
  1. **Sensitive Data:**

Votes are stored immutably on the blockchain, ensuring that they cannot be altered or tampered with once submitted.

* 1. **Non-Sensitive Data**

Voter profiles, election logs, and other non-critical information are stored in secondary database, optimizing the system's speed and reducing blockchain congestion.

* + 1. **Result Display:**
  1. **Real-Time Updates:**

Once voting is complete, the system uses smart contracts to process and count votes. The results are automatically updated and displayed in real-time through the mobile app, with both list and graphical formats available for users.

* 1. **Transparency:**

Since votes are recorded on the blockchain, the result calculation process is transparent and auditable, enhancing the election's credibility.

* 1. **Security Measures**
     1. **End-to-End Encryption:**

All communications between the app, backend, and blockchain are encrypted to prevent unauthorized data interception.

* + 1. **Smart Contracts for Security:**

Solidity-based smart contracts manage vote validation, counting, and result declaration, ensuring accuracy and security.

* + 1. **MFA & Biometrics:**

Multi-factor authentication and optional biometric login provide additional layers of security, preventing unauthorized access to the voting system.

**Blockchain-Based Voting Security:**

The system draws on research, such as the secure electronic voting systems outlined [2], which emphasize the use of blockchain and mobile technologies for privacy and security in elections.

**Scalability Insights:**

The system's architecture takes lessons [16], which addresses scalability challenges in blockchain- based applications, ensuring that the voting system can handle high voter turnout without compromising performance.

The methodology combines cutting-edge blockchain technology, a secure backend, and optimized data handling using secondary database to build a robust, scalable, and secure online voting system. The use of smart contracts, MFA, and real-time results ensures the system’s transparency and trustworthiness, while performance optimizations make it feasible for large-scale elections globally.

4.6 Test case Dsign

**4.6.1. Authentication Test**

1. **Description**: Verify that the user authentication system works correctly with multi-factor authentication (password, biometric, OTP).
2. **Input**: Voter enters email/password, biometric data, and receives OTP.
3. **Expected Output**: Successful login, access granted to the dashboard.

**4.6.2 Vote Casting Test**

1. **Description**: Ensure that votes are securely cast and recorded on the blockchain.
2. **Input**: User selects election and candidate, confirms vote.
3. **Expected Output**: Vote is recorded on the blockchain, transaction hash is returned, and confirmation message is displayed to the user.
   * 1. **Duplicate Voting Prevention**
4. **Description**: Ensure that users cannot vote more than once in the same election.
5. **Input**: User attempts to cast a vote for the second time in the same election.
6. **Expected Output**: Error message indicating that the user has already voted, and no new transaction is created on the blockchain.

**4.6.4 Result Display Test**

1. **Description**: Validate that real-time results are fetched from the blockchain and displayed correctly.
2. **Input**: User queries election results after voting ends.
3. **Expected Output**: Real-time results fetched and displayed from the blockchain, showing vote counts by candidate and overall turnout.

**4.6.5. Data Encryption and Security Test**

1. **Description**: Verify that all sensitive data, including votes and user details, are encrypted during transmission and storage.
2. **Input**: Vote data submitted by the user.
3. **Expected Output**: Data is encrypted during transmission, verified by checking the blockchain records and ensuring sensitive information remains confidential.

**4.6.6. Scalability Test**

1. **Description**: Assess the system’s ability to handle a high number of concurrent users.
2. **Input**: Simulate thousands of users casting votes simultaneously.
3. **Expected Output**: The system should process all votes with minimal latency and no downtime, showing no degradation in performance.

**4.6.7. Failover and Recovery Test**

1. **Description**: Ensure that the system can recover from failures such as server crashes or blockchain node disconnection.
2. **Input**: Simulate a backend server crash during voting.
3. **Expected Output**: The system automatically switches to a backup server with no data loss or impact on ongoing voting processes.

**Chapter 5**

**Result and Discussion**

**5.1 Expected Outcome:**

The **Online Voting System Using Blockchain** is expected to deliver the following key outcomes:

**5.1.1 Secure Voting Process:**

* + 1. **Immutable Vote Recording:**

Votes cast through the mobile app will be stored immutably on the Ethereum blockchain, ensuring that they cannot be tampered with or altered after submission. This guarantees the integrity of the voting process.

* + 1. **Real-Time Results:**
    2. **Transparency and Speed:**

The system will display election results in real-time, with both textual and graphical representations of the number of votes each candidate has received. This feature will enhance transparency, allowing both voters and election officials to monitor results as they are tallied.

* + 1. **Auditability:**
  1. **Comprehensive Election Logs:**

Election-related data, such as voter participation, metadata, and activity logs, will be stored in secondary database, enabling election officials and auditors to review the process without compromising voter anonymity. This ensures a transparent and auditable electoral process.

* + 1. **Cost Efficiency:**
  1. **Reduction of Election Costs:**

By leveraging blockchain technology and reducing the need for physical voting machinery like Electronic Voting Machines (EVMs), the system significantly cuts costs associated with running elections. Additionally, it minimizes manpower requirements, making it more cost-effective for large-scale national elections.

* + 1. **Scalability and Performance:**
  1. **Handling Large Voter Bases:**

The system is designed to handle high user loads during peak election periods, such as national elections. The use of transaction batching and offloading non-sensitive data to secondary database ensures that the blockchain remains scalable and efficient.

* + 1. **Enhanced Security:**
  1. **Multi-Factor Authentication (MFA):**

The system ensures that only verified voters can access the platform and cast votes, adding an extra layer of security to prevent unauthorized access.

* 1. **End-to-End Encryption:**

All communications between the mobile app, backend, and blockchain are encrypted, further enhancing the security of voter data and the election process.

* + 1. **User Engagement and Voter Participation:**
  1. **Participation Tracking:**

The system provides features that allow election officials to track voter participation in real-time. This information can be used to improve voter turnout and identify patterns in voter behavior.

The system is expected to deliver a secure, transparent, and cost-effective solution for conducting elections, capable of scaling for both local and national elections in India and globally. By leveraging blockchain technology for vote storage and using secondary database for additional data management, the system ensures performance, security, and transparency while maintaining voter privacy.

* 1. **Challenges and Solutions:**
     1. **Blockchain Scalability**

1. **Challenge:**

Public blockchains like Ethereum, while highly secure and decentralized, face scalability limitations. During large-scale elections, the sheer volume of transactions can lead to network congestion, increased transaction times, and higher costs due to fluctuating gas fees.

**2. Solution:**

* **Layer 2 Scaling Solutions:**

The integration of Layer 2 protocols (e.g., rollups or sidechains) allows for faster and cheaper transactions by processing them off-chain before settling them on the main Ethereum chain. This ensures that high voter turnout can be handled without overwhelming the network.

* **Private Blockchain Option:**

As an alternative, a private or permissioned blockchain could be considered. Private blockchains offer greater control over transaction throughput and cost, making them ideal for large, national elections that need high transaction capacity.

* **Transaction Batching:**

Instead of submitting each vote individually, transactions are grouped into batches and processed together. This reduces the number of interactions with the blockchain and helps to optimize performance, particularly during peak voting periods.

* + 1. **Security Threats**

1. **Challenge:**

The system is vulnerable to various cybersecurity threats, including Distributed Denial-of-Service (DDoS) attacks, unauthorized access, and data breaches. Ensuring that the system remains secure from such attacks is critical for maintaining voter trust and election integrity.

1. **Solution:**

* **Strong Encryption:**

End-to-end encryption is applied to all communications between the mobile app, backend, and blockchain to ensure that sensitive data remains secure during transmission.

* **Multi-Factor Authentication (MFA):**

MFA, which includes biometric authentication (fingerprint, facial recognition) and OTPs, is enforced to protect voter accounts and prevent unauthorized access to the system.

* **Rate Limiting & DDoS Protection:**

The system employs rate limiting on API calls and backend functions to protect against DDoS attacks. Regular penetration testing and security audits further ensure the robustness of the system against external threats.

* **Smart Contract Audits:**

All smart contracts are rigorously audited to prevent vulnerabilities and ensure they execute voting processes securely.

* + 1. **User Privacy**

1. **Challenge:**

Maintaining voter privacy is essential, especially in an electronic voting system. Sensitive data, such as voter identities and votes, must be protected, and the anonymity of votes should be guaranteed without compromising the integrity of the election.

1. **Solution:**

* **Data Segregation:**

The system isolates sensitive vote data on the blockchain, which provides tamper-proof storage and ensures anonymity. Meanwhile, non-sensitive data, such as voter profiles, election metadata, and activity logs, are stored in Firebase to optimize performance and reduce blockchain costs.

* **Data Encryption:**

All voter information, including non-sensitive data stored in Firebase, is encrypted at rest and in transit to ensure that no unauthorized entity can access or tamper with it.

* **Audit Logs:**

The system generates comprehensive audit logs that election officials can use to verify the integrity of the election without compromising the privacy of individual voters.

By addressing the challenges of **scalability**, **security**, and **user privacy**, the **Online Voting System Using Blockchain** can provide a reliable, secure, and efficient platform capable of handling large- scale elections, such as those in India, while maintaining voter trust and election transparency.

# Chapter 7

# Conclusion

### Conclusion

The **Blockchain-Based Online Voting System** developed in this project represents a significant advancement in the electoral process, particularly in large-scale scenarios such as those encountered in India. The integration of **Ethereum’s blockchain technology** with a **secondary database** creates a secure, scalable, and efficient platform for conducting elections.

By utilizing blockchain, the system ensures that votes are recorded immutably, providing a robust mechanism to prevent fraud and vote tampering. The decision to incorporate a secondary database, such as **Firebase**, allows for the effective handling of non-sensitive data, optimizing system performance and reducing operational costs. This hybrid approach addresses critical challenges associated with traditional voting systems, including security vulnerabilities, inefficiencies, and high costs.

The proposed system effectively tackles issues of scalability through techniques like **transaction batching** and the potential implementation of **Layer-2 solutions**, ensuring it can accommodate a high volume of votes during peak times. Furthermore, the use of **end-to-end encryption**, **multi-factor authentication (MFA)**, and comprehensive **audit logs** enhances the overall security of the voting process. Real-time result processing and transparent auditing mechanisms instill greater confidence among voters, reinforcing trust in the electoral system.

In summary, the blockchain-based voting system presents a transformative step toward modernizing elections, offering a viable and trustworthy solution for secure, scalable, and efficient democratic processes. By minimizing reliance on manual processes and traditional voting machines, this system significantly contributes to the evolution of electoral systems in the digital age.

### Future Scope

The future enhancements of the **Blockchain-Based Online Voting System** can focus on several critical areas to further improve scalability, privacy, and functionality:

1. **International Expansion**:  
   The system can be adapted for use in international elections, allowing it to cater to specific electoral requirements across different countries and regions. This adaptation would involve customizing the user interface and ensuring compliance with local election laws and regulations.
2. **Enhanced Privacy Features**:  
   The exploration of advanced encryption techniques, such as **homomorphic encryption** or **zero-knowledge proofs**, can significantly bolster voter privacy while maintaining transparency. These methods would allow for vote validation without exposing sensitive voter information, further enhancing public confidence in the system.
3. **Layer-2 Scaling Solutions**:  
   Further investigation into Layer-2 solutions, such as **rollups** or **sidechains**, could improve transaction throughput and efficiency. Implementing these technologies would enable the system to handle an even greater number of votes during high-traffic elections without compromising performance.
4. **Biometric Security Enhancements**:  
   Integrating additional biometric authentication methods, such as **facial recognition** or **voice biometrics**, could further enhance security. These measures would provide voters with more options for secure authentication while ensuring that the voting process remains quick and user-friendly.
5. **Artificial Intelligence and Machine Learning Integration**:  
   The application of **AI** and **Machine Learning (ML)** techniques can be utilized to analyze voting patterns, assess voter behavior, and predict election outcomes. This data-driven approach would provide valuable insights to election authorities, facilitating better decision-making and strategies for improving voter engagement.
6. **User Feedback Mechanisms**:  
   Implementing systems for gathering user feedback on the voting process could help identify areas for improvement. This feedback would be invaluable in refining the user experience and addressing any potential concerns raised by voters.
7. **Continuous Security Updates**:  
   As technology evolves, so do potential threats. Establishing a robust framework for ongoing security assessments and updates will be essential to maintaining the integrity of the voting system over time.

By pursuing these directions, the **Blockchain-Based Online Voting System** can evolve into a more robust, secure, and scalable platform suitable for global adoption. These enhancements will not only improve the system's functionality but also reinforce the public's trust in electronic voting systems as a reliable method for conducting elections.

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**NOTES 🡪**

Hardware and Software Requirements

Specifically pending to add from ppt to here respective chapter