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The Future of Democracy: Exploring the Potential of Block chain-Based Digital Voting Systems

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ABSTRACT

A key component of democratic governance in modern countries is the election process. But due to worries about things like polling booth capturing, data manipulation, and vote rigging, a general mistrust in the electoral process has evolved. Because they put election data under the authority of outside organizations, both the traditional and computerized voting systems now in use lack the required transparency. Voters have few options to verify that election administrators will carefully and accurately count their votes due to a lack of openness. To create an electronic voting (e-voting) system that upholds the ideals of fairness and security, it is imperative to take advantage of developing technology, particularly blockchain. When correctly applied, blockchain technology's public distributed ledger holds the potential to make tampering almost impossible. In this regard, our research suggests a decentralized electronic voting system that makes use of blockchain technology as a remedy to deal with the aforementioned issues. Through the elimination of the possibility of centralized election control, this approach seeks to reduce the dangers connected with conventional election procedures and increase voter confidence. The suggested method offers a tamper-proof, transparent, verifiable, economical, and reliable voting process through the distribution of control across several governing and non-governing bodies. This paper examines the development and implementation of such a blockchain-based electronic voting system, shedding insight on how it may enhance the openness and accessibility of democratic elections in contemporary societies.

Keywords : E-Voting, Blockchain, Electronic Voting System, Blockchain Technology

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I. INTRODUCTION

An election is a significant part of the democratic system implemented in modern societies but a large number of the population distrust the election system due to polling booth capturing, data manipulation, and vote-rigging [1]. The paper discusses the major setbacks in current voting systems and analyzes the application of blockchain technology in E-voting and its impact on securing the voting systems from possible security breaches. Blockchain is a distributed ledger that can reduce the chances of data manipulation and ensure secure voting during elections [2].

The most common problem in elections is the issue of transparency, data manipulation, and security. Election systems still use a centralized system and there is one body that regulates it. Having full control over the databases makes them vulnerable to possible data alternations by the governing body. Countries like the United States, India, and Japan still suffer from a flawed electoral system. Distributed ledger technology or blockchain; an open or distributed data infrastructure providing secure communications without a centralized third party over the internet, is known to have a disruptive potential relative to that of the internet (Hardwick et al., 2018). Technological innovation is inspiring major policy and strategic activities in numerous countries, especially in five digital countries i.e. Israel, the United States, the United Kingdom, New Zealand, and Estonia [2].

There is now ample work on the benefits of implementing e-voting systems using blockchain technology. Meanwhile, in D5 countries, extensive research has been devoted to the application of decentralized technology in elections [2]. However, there is a huge research gap in identifying the potential of this technology and applying it to the voting system in developing countries [3]. Pakistan is also one of those countries where very limited research has been done on it. As a federal parliamentary democratic republic, the voting system in Pakistan is an integral part of selecting the country's next government but the claims of fraud overshadow the elections leading to bloodshed [4]. In order to avoid election officials' misconduct, Pakistan has created a biometric verification system to collect voter fingerprints at voting places [5]. This method limits the power of polling officials through the use of technological technology. However, while the technology offers security to some extent [6,] transparency continues to be a major concern.

BLOCKCHAIN

Blockchain is a growing collection of data that is encrypted and connected together. Blocks are records that each contain a cryptographic hash of the block before it, a nonce, transaction information, and a timestamp. With the use of a distributed open ledger, it is possible to effectively, permanently, and independently verify the transactions between two parties. Blockchain is often run by a peer-to-peer network that complies with a protocol for communicating between nodes and verifying new blocks. There are now four types of blockchain networks: private, consortium, public, and hybrid [8]. This unique architecture of a peer-to-peer (P2P) network distributes responsibilities and duties between peers, see Figure 1. Unlike server-based networks, the P2P network provides the peers/nodes equal privileges to contribute to the application.

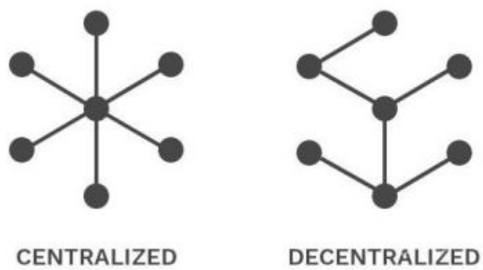

Figure 1: Difference between a centralized and a decentralized (P2P) network

We have taken Bitcoin as an instance to understand how the blockchain works. Bitcoin is known throughout the world as the first decentralized digital cryptocurrency plus the first application of blockchain technology. The transactions can take place directly among the users who are verified by the validation nodes termed as miners. A public ledger enlists the transactions, distributed among nodes present in the network we know as blockchain. Every particular transaction that has ever happened in the system is encapsulated in a "block". Figure 2 illustrates the infographics of a standard blockchain system.

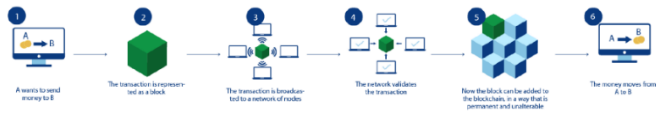

Figure 2: Working of a blockchain

II. CONSENSUS ALGORITHM

Obtaining consensus among blockchain network nodes on a certain object is known as the consensus issue. The control unit in centralized systems is able to concur on the real entities and publish them over the whole network. However, nodes in the distributed ledger network must collaborate and work together without the benefit of a centralized authority. In other words, a blockchain's consensus process aligns all of the network's nodes to obtain the same understanding of every transaction. How a deal may be reached on a decentralized blockchain network is the issue at hand. Even if all peers in a P2P network are reliable, the question of permission vs consensus may still arise. In such cases, a consensus law known as the "longest chain" can be used to distinguish between a legitimate block and an unethical block. A miner will lengthen a path when they decide to accept it as legitimate, and it is thought that this represents a vote in favor of the way's acceptance.

III. METHODOLOGY

To develop an e-voting system, one must satisfy the properties (Voter and ballot privacy, Individual verifiability, Accuracy, Eligibility, Uniqueness of votes, and Fairness) that make the system fair and secure. So, to satisfy these properties, the procedures and techniques we have employed are discussed in this section.

The traditional paradigm of voting infrastructure is centralized i.e. government alone oversees the election system, as shown in Figure 3. [25] The e-voting infrastructure is maintained centrally by the government under this paradigm, which has a fatal fault since it renders the entire process worthless because the system is no longer impervious to manipulation. In order to tamper with votes in an electronic voting system that is controlled by the government, unscrupulous individuals just need to get access to the government's network.

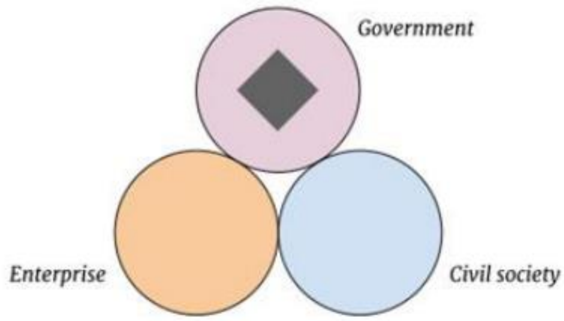

Figure 3 : A centralized and government-run e-voting system. The black diamond represents the e-voting infrastructure

In order to make tampering nearly impossible, the ideal model for an electronic voting system must be strongly dispersed. A blockchain-based electronic voting system, like the one shown in Figure 4 [25], may be thought of as a completely distributed system. This indicates that it is an appropriate structural implementation of a private blockchain: The network is set up to be tamper-proof, and each entity provides an equal contribution to the upkeep of the blockchain-based electronic voting system. Since no entity has control over the majority of the blockchain network, fairness, accuracy, and robustness of the election are ensured until 51% of the network remains uncompromised and honest.

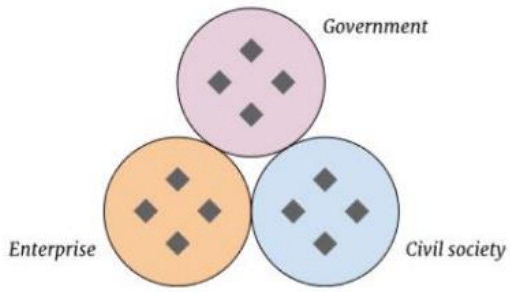

Figure 4 : A properly distributed blockchain-based e-voting system.

IV.CRYPTOGRAPHY

V.1 RSA CRYPTOSYSTEM

One of the first public-key cryptosystems, RSA is used to communicate data securely. The two different prime integers p and q are used to construct the RSA public/private key combination. While the decryption key (private key) must be kept secret, the encryption key (public key) is public. And the two keys are asymmetric i.e. private key cannot be derived from the public key. The standard key length or size(in bits) of the RSA modulus is a minimum of 1024, but 2048 is recommended [26].

V.II VOTER AND CANDIDATE REGISTRATION

The voter and candidate registration process is out of the scope of our project prototype since it is quite simple and can be implemented using previous research or studies. So, we expect to get legally registered voters and candidates. On the other hand, a registry of voters will surely be maintained at every node to avoid double voting and ensure uniqueness in the voting system.

V.III ALLOCATION OF THE TOKEN

A vote is recorded just once thanks to the use of a token-based blockchain. When creating keys, it is inserted into the voter's wallet. When a voter picks a certain candidate, the token is added to their wallet and kept on the distributed ledger forever. A vote is the name of the token.

V. UML DIAGRAMS

VI.I DEPLOYMENT DIAGRAM

This system will be deployed on two platforms, both Web and Mobile. The mobile application will be deployed on a Tablet PC that will be placed in every polling station and will be used to cast votes. The web portal will display the results, as shown in Figure 5. While the validation nodes will serve as an HTTP server to the front end. The front end communicates with the API to send requests and receive a JSON response.

Since this is a data-centric product it will need somewhere to store the data. For that, a distributed ledger will be used. Both the mobile application and web server will communicate with the mining nodes holding the blockchain's distributed ledger, however in slightly different ways. The web portal will only use the database to cache the data and show the results after the election ends. While the mobile device will be a partial node. So, the voter will cast a vote using the mobile application and all the communication will go over the blockchain network through the API routes.

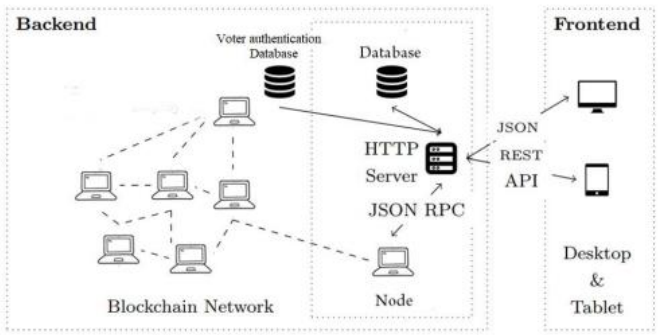

Figure 5: Deployment diagram

VI.II SEQUENCE DIAGRAM

The sequence diagram follows the overall strategy that our blockchain-based electronic voting system suggests, which is in line with other blockchains already in use, including Bitcoin.

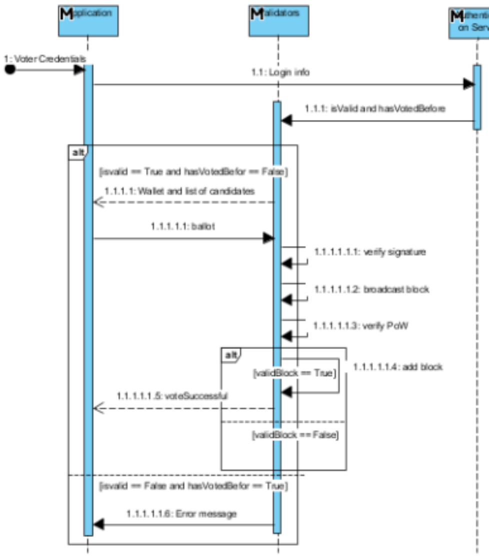

Figure 6 : Sequence Diagram of voting phase

VI.I II CLASS DIAGRAM

The class diagram shown in the below figure shows the system's classes, attributes, and relationships among the objects which depict the structure of the TessChain API.

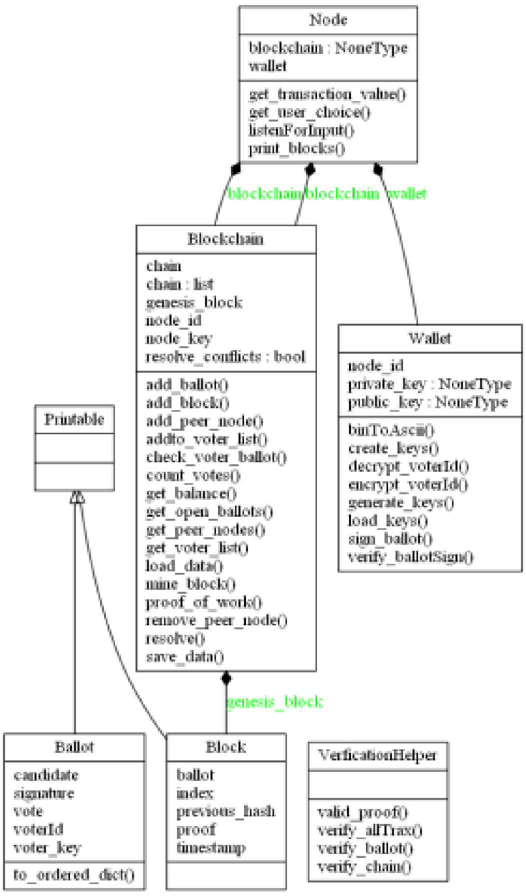

Figure 7: Class Diagram

VI.API ENDPOINTS

There are five main endpoints through which the front end communicates with the API and stores the ballots on the blockchain. First, the validation node API needs to be set up by executing the main.bat file. The script has some default parameters, port number, and node ID. Node ID for the identification of the node and port number for the port that you want to open for incoming and outgoing traffic.

```
PS D:\Git\Projects\FYP\source\TessChain> python node.py -p 4040 -n ECP1
 * Serving Flask app "node" (lazy loading)
 * Environment: production
   WARNING: Do not use the development server in a production environment.
   Use a production WSGI server instead.
 * Debug mode: off
 * Running on http://0.0.0.0:4040/ (Press CTRL+C to quit)
```

Figure 8: First validation node setup on port 4040

```
PS D:\Git\Projects\FYP\source\TessChain> python node.py -p 4041 -n ECP2
 * Serving Flask app "node" (lazy loading)
 * Environment: production
   WARNING: Do not use the development server in a production environment.
   Use a production WSGI server instead.
 * Debug mode: off
 * Running on http://0.0.0.0:4041/ (Press CTRL+C to quit)
```

Figure 9: Second Validation node setup on port 4041

Here we have set up two validation nodes, having port numbers 4040 and 4041 with node ID ECP1 and ECP2 respectively.

Initializing validation node wallet

The next step after starting the server will be creating a wallet for the validation node. The endpoint “node_wallet” is called using a POST method to the API for creating the wallet, and it is called automatically when the main.bat file is executed. It responds with the node’s public/private key pair, shown in the following figure.

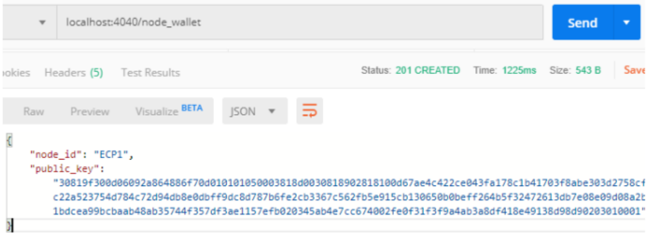

Figure 10: JSON response of "node_wallet" API endpoint

Initializing voter wallet

The validation node is set up, and now we move to the voting process. After the voter's authentication, a wallet has to be created to cast a ballot. When the voter logs in the "wallet" endpoint is called and it responds with the voter's public/private key pair, and the VOTE token is placed into that wallet by the node.

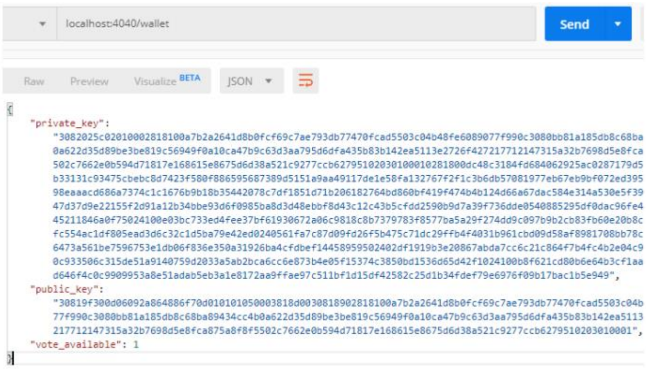

Figure 11: JSON response of "wallet" API endpoint

Casting ballot

After the wallet creation, the voter can select a candidate and cast a ballot. A request is sent to the "ballot" endpoint along with JSON data that contains the voter's choice when the voter confirms the ballot, and in response, the API broadcasts the ballot information (candidate, voter key, signature, and encrypted voter ID, shown in the figure to the peer nodes for validation.

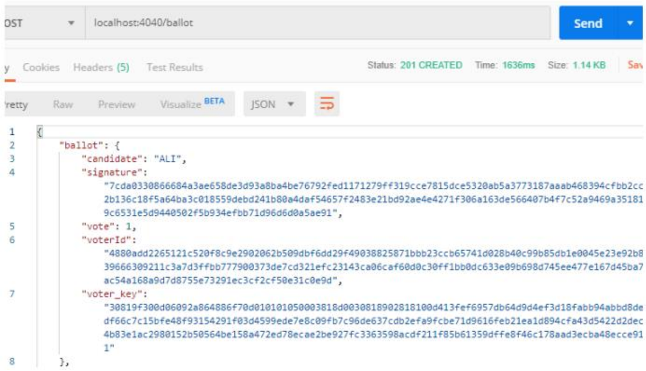

Figure 12: JSON response of "ballot" API endpoint

Vote count

After the voting process ends, the "count_votes" endpoint will be triggered by the tallying server to display the result of the web app. For testing, a GET request is sent to the server to count votes for a candidate (ALI in this case), as shown in the figure.

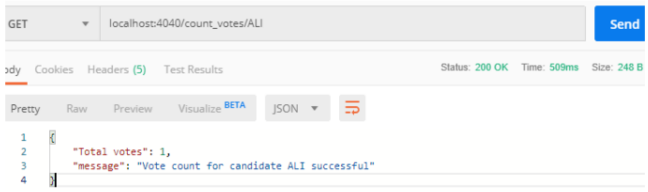

Figure 13: JSON response of "count_votes" endpoint

Ballot verification

To verify the voter's ballot, a request is sent to the "check_ballot" endpoint along with JSON data that contains the voter's ID, public key, and private key. The public key is to improve the searching time, and the private key is to decrypt the voter ID and check if the decrypted text matches the ID. Only then it will return the voter's ballot, as shown in the figure.

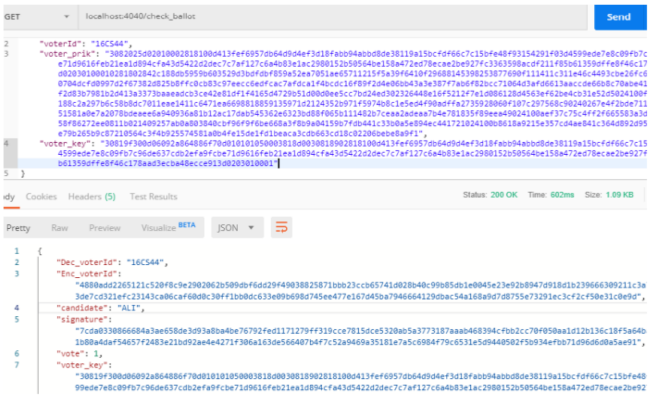

Figure 14: JSON response of "check_ballot" endpoint

VII. HIGH THROUGHPUT TECHNIQUES

In this blockchain-based digital voting system, we have employed several techniques and frameworks to enhance high throughput and scalability while maintaining the system's security and integrity:

Parallel Processing with Hadoop:
Implemented a parallel processing technique using the Hadoop framework to distribute the processing load across multiple nodes. Hadoop's MapReduce paradigm can be used to process and analyze large volumes of voting data in parallel, making it suitable for handling massive numbers of votes and ensuring high throughput.

Apache Spark for Real-Time Data Processing:
Utilized Apache Spark for real-time data processing and analysis. Spark's in-memory processing capabilities can be valuable for quickly handling and verifying votes as they are cast, ensuring that the voting process remains efficient and responsive.

Sharding the Blockchain:
Implemented a sharding technique to divide the blockchain into smaller, more manageable parts. Each shard can handle a subset of voting transactions, allowing for parallel processing and reducing the overall computational load. This can significantly enhance the scalability of the blockchain-based voting system.

By implementing these techniques and frameworks, a blockchain-based digital voting system can achieve high throughput, scalability, and enhanced security, ensuring a transparent and efficient democratic election process.

VIII. RESULTS AND DISCUSSION

Figure 15, is the login user interface for the voters, they need to provide their ID and email. An email will be generated with the voter's public and private key when logged in.

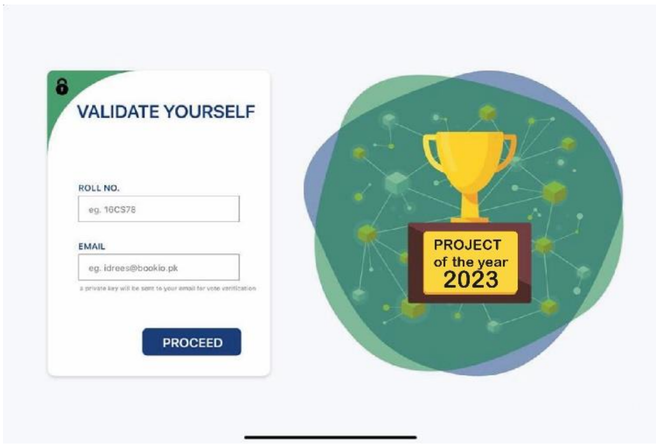

Figure 15: Login screen for the voter

Figure 16 shows the candidate list, the voter must select one candidate to cast a ballot.

Figure 16: List of candidates

Figure 17 shows the ballot confirmation screen. The voter can return and again select another candidate if he selected the candidate by mistake or the voter changes his mind.

Figure 17: Ballot confirmation screen

In a decentralized environment, the load that each node handles and the time taken increase with the increase in the number of participants or validation nodes. We performed a simulation of the system, to verify that our system can handle scenarios with a large number of nodes in the network. The simulation is done by using Python programming using the VS code testing extension. The results of the simulation of the blockchain (containing 1000 blocks) running on our TessChain API are given in Table 1. The time taken to cast and mine a block also includes the time taken to sign, verify, and broadcast the ballot, plus the time taken to calculate and verify the PoW.

Table 1: Performance test results

Number of nodes	Cast ballot	Mine block	Tallying	Verify ballot
3	863ms	3586ms	496ms	603ms
10	897ms	3694ms	503ms	602ms
50	1636ms	4068ms	522ms	657ms
100	1890ms	4319ms	497ms	635ms
500	2965ms	5454ms	550ms	668ms
1000	4526ms	6813ms	531ms	670ms

In addition, the relation between times with the number of nodes can be simulated, and visualization concerning the number of election places in a large-scale election.

IX. CONCLUSION

In conclusion, this research provides a comprehensive overview of global voting techniques and technologies, with a specific focus on Pakistan's electoral methods. Despite Pakistan's long-standing commitment to democracy, the nation still relies on outdated voting techniques for its critical leadership elections. The study also highlights the drawbacks of centralized e-voting systems, emphasizing the vulnerability of central databases to manipulation. To address these issues, a more secure and tamper-proof approach is proposed, utilizing a decentralized backend, with a particular emphasis on blockchain technology. Blockchain-based electoral procedures offer a solution to the problems associated with centralized voting systems.

As part of this research, we implemented a prototype API called 'TessChain' to showcase the decentralized voting features discussed. To enhance this work, future research can explore various blockchain attributes and encryption techniques, as well as different consensus protocols. 'TessChain' has the potential for further development into a comprehensive voting API or for supporting the implementation of other blockchain-based applications, marking a significant step forward in modernizing electoral processes.

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