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DECENTRALIZED ELECTRONIC VOTING WITH ETHEREUM BLOCKCHAIN IN DEMOCRATIC AND POLITICAL ELECTIONS

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ABSTRACT

The Ethereum blockchain-based electronic voting (e-voting) systems can emerge as a viable strategy in this era of contemporary democracies to revolutionize political elections and augment the efficacy of the electoral process. There are myriad advantages that the Ethereum blockchain has to offer, from fairness to increased voting rates. Unlike traditional voting protocols, the Ethereum blockchain can assure substantial cost savings and eliminate the necessity for electoral intermediaries. The use of the Ethereum blockchain in political contexts also ensures that elections are held with integrity while preserving the voters' privacy. Due to its popularity, provision of smart contracts logic, and various promising advantages, this systematic review aims to examine the potential deployment of decentralized e-voting systems integrated with Ethereum blockchain technology for democratic political elections. A systematic literature review (SLR) and the

PICO approach, which stands for population, intervention, control, and outcomes, were adopted in this study to systematically analyze the existing literature. Key technological approaches identified in the voting system include the hybrid blockchain and privacy-preserving score voting. Among the noteworthy findings are the following: while adoption and complexity remain challenges across numerous e-voting frameworks, scalability, end-to-end security, enhanced efficiency, and effectiveness are key benefits. An exploration into the prospective future innovations, such as the integration of artificial intelligence and big data analytics into the Ethereum blockchain, was also included to further improve the reliability of the e-voting systems. It is believed that the Ethereum blockchain has a promising transformative impact on electoral politics and democratic processes, presenting a ray of hope for future elections.

Keywords: Electronic voting, Ethereum blockchain, politics, election, democracies.

INTRODUCTION

In modern democracies, technology can potentially become an integral part of the political electoral process in different stages: before, during, and after elections. Leveraging electronic voting (e-voting) promises notable cost advantages over conventional electoral procedures. Furthermore, it aids in disseminating voting data among a network of nodes and obviates the necessity for a central body or intermediary. Technology can be useful in constructing voter records and registration, establishing electoral boundaries, managing election officials, ballot printing, casting ballot records, vote tallying, compiling as well as broadcasting election results. In terms of election organization, accountability in political matters, and management of expenses, technology can be beneficial in several ways when it is being utilized effectively (Khan et al., 2019). Conversely, the lack of access to cutting-edge technologies may present significant challenges, particularly in large-scale election planning. However, if Ethereum blockchain technologies serve as the basis for the political e-voting system, then the landscape may undergo worthwhile transformation.

With the integration of Ethereum blockchain technological advances, the entirety of the electoral procedures can be made more inclusive.

Principally, the Ethereum blockchain is a decentralized platform that verifies and processes tamper-resistant transactions. The ability to automate various voting procedures is made possible by Ethereum's smart contract capabilities, which streamline the process and are less prone to human errors. Moreover, voting data can potentially be safeguarded against manipulation and tampering, thanks to the Ethereum blockchain, which promotes political integrity and immutability. In this context, the blockchain records every vote as a transaction, resulting in voting results that are transparent and verifiable. Indeed, this innovative approach marks a significant advancement in the security of electoral processes through the Ethereum blockchain. The deployment of e-voting systems can be observed in countries like Estonia, where it emerged as a pioneer in introducing and fully applying e-voting systems into its political elections particularly, during their 2013 Estonian local municipal elections and the 2014 European Parliament elections. One noteworthy result is that among participants who opt to vote online, there is a remarkable rise in voter turnout, which underscores the effectiveness of e-voting (Heiberg & Willemson, 2015). In addition, the adoption of e-voting was also established in Brazil (Avgerou, 2013), where the general election was declared a success because the percentage of blank votes cast for the president, governor, federal deputy, and state deputies reduced when e-voting machines were used (Nicolau, 2015). Another one of the few countries that have adopted the e-voting trend is Switzerland (Koç et al., 2018).

As interest in e-voting continues to grow, the integration of blockchain into voting systems holds the potential to influence the future of democratic governance in elections. Given the prevailing literature, there is an increasing exploration into how blockchain technology can help revolutionize electoral processes, ensuring that confidentiality and impartiality are maintained throughout the implementation of the voting protocols (Khan et al., 2019). Hence, it is not surprising to discover that blockchain-integrating voting systems have been proposed as the next development of e-voting (Çabuk et al., 2018). Certain governments have already deployed e-voting systems built upon the Ethereum blockchain for elections (Adiputra et al., 2018). Jordan is one of the countries that utilize the Ethereum-based E-Voting System (EBVS) to tailor it for the Jordanian parliament election. In this system, a voter first selects an option from the menu that represents a political party or alliance of candidates. Subsequently, within

the menu, the voter can choose to vote for one or more candidates (Malkawi et al., 2023).

It is well understood that election integrity is essential in all democracies to instill public trust and accountability among voters and across societies, ensuring that citizens' voices and decisions are represented in governance. In this regard, aligning with the pursuit of integrity and legitimacy in electoral processes, an existing study (Ibrahim et al., 2021) supports the notion that adopting e-voting techniques can improve security measures, thereby bolstering the accountability of elected officials and fostering civic engagement. While previous findings have touched on the concept of the Ethereum blockchain for e-voting, the challenges in implementing it, evaluating the system's merits, and advancements associated with its adoption have not been thoroughly scrutinized. Compelled to adopt a voting system that is both intelligent and manageable for pertinent political parties to access reliable data on long-term assets, this systematic review aims to explore the advantages of Ethereum-based voting systems. Notably, it also represents a pioneering endeavor in examining the use of the Ethereum blockchain approach from various aspects, including challenges and future innovations, specifically for e-voting in democratic and political elections.

To provide a thorough understanding of this field, the systematic review is organized into different sections: the first section presents the introduction of the study in the context of e-voting, Ethereum blockchain, and its variations; the second section details the methodology process for analyzing relevant literature; the third section discusses the advantages of decentralized e-voting using Ethereum blockchain in political election processes; and the fourth section highlights the potential challenges faced and future innovations of this advancement. Finally, the conclusion follows, where this review concludes with a summary of the main findings.

METHODOLOGY

A systematic literature review, or SLR, is conducted in this study. In this review, several key steps are crucially involved to ensure a thorough examination and evaluation of the existing literature: identification, screening, establishing eligibility, and data extraction (Figure 1).

Inclusion and Exclusion Criteria

A set of criteria for inclusion and exclusion was developed to filter the database search results. Articles eligible for inclusion are those focused on e-voting systems that use the Ethereum blockchain in political elections. On the other hand, excluded articles are those that did not fit these criteria or were not accessible in English. To make sure that the publications are relevant and up-to-date, only articles that had been released in the last 10 years were included.

Search Strategy and Identification

The Population, Intervention, Comparison, and Outcomes (PICO) approach was used to develop the study questions.

1. P: Population – Articles that described Ethereum blockchain-based e-voting systems for large-scale or small-scale elections were studied.
2. I: Intervention – Data on e-voting systems developed using Ethereum blockchain technology were gathered.
3. C: Comparison – The results of the study were not compared.
4. O: Outcomes – The real-world application, advantages, drawbacks, and potential future advancements of blockchain-based e-voting systems were understood.

The search strategy involved the use of certain keywords in targeted searches across a range of scholarly resources and platforms. Relevant articles were typically identified and retrieved using keywords associated with this systematic review, such as "electronic voting," "Ethereum blockchain," "political election," and similar terms. Among the platforms that were searched are Google Scholar, Scopus, ScienceDirect, and SpringerLink. In addition to that, hand-searching of pertinent journals was carried out to produce a thorough search and ensure that a wide range of searches was covered. As a result, a total of 612 articles were identified. After the removal of 450 duplicates, all the remaining articles were then subjected to the screening process.

Screening and Selection of Studies

This phase was conducted objectively, with two independent reviewers assessing each article for inclusion. Any discrepancies among the reviewers were swiftly settled via thoughtful deliberation

and consensus, assuring the credibility and integrity of the screening protocol. To ensure that only relevant articles were included, it was essential to conduct screening using a multi-stage process. Based on the titles and abstracts, the identified articles were carefully screened to determine their potential eligibility. During the screening process, 198 articles with titles deemed irrelevant would be excluded. Following predetermined inclusion and exclusion criteria, the full-text articles relating to the studies were all assessed. Another round of abstract screening was then applied to 252 articles to guarantee their eligibility.

Data Analysis and Trustworthiness Measures

A coding form was developed to guide the process of executing the thematic analysis for all selected studies. The data were categorized and coded separately according to themes by independent reviewers. Once again, any discrepancies that emerged were discussed and resolved immediately. Facilitated by using forms that serve as references for theme organization, themes were easily and iteratively identified to reach conclusions, offering insights into the study's research questions. To preserve a nuanced data interpretation throughout the analysis, it is crucial to include the reviewer's perspectives. Simultaneously, peer debriefing sessions were performed to validate interpretations and help improve the overall verifiability of the findings.

Eligibility

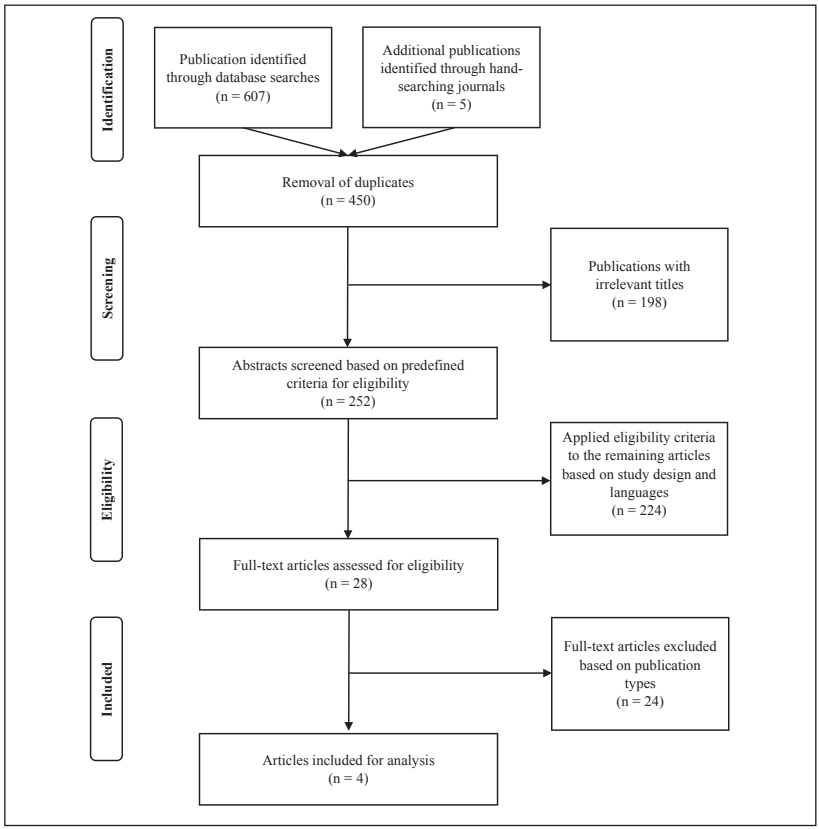
A vital step in ensuring that the selected articles were compiled with the specific standards was to establish the eligibility criteria. The abstracts were thoroughly screened in selecting articles from the pool that were found to be closely relevant and could best answer the research question. It is followed by subjecting 224 articles to eligibility criteria in terms of the research design and languages. Consequently, only 28 articles proceeded to further assessment. Based on publication types, 24 were excluded, leaving four publications for data extraction.

Data Extraction and Synthesis

In this data extraction and synthesis process, the four selected articles underwent an extensive review and synthesis to extract relevant data. Subsequently, the extracted information was synthesized across the selected articles to identify the common trends, revelations, and insights.

Figure 1

Flowchart Illustrating the Systematic Review Methodology



RESULTS

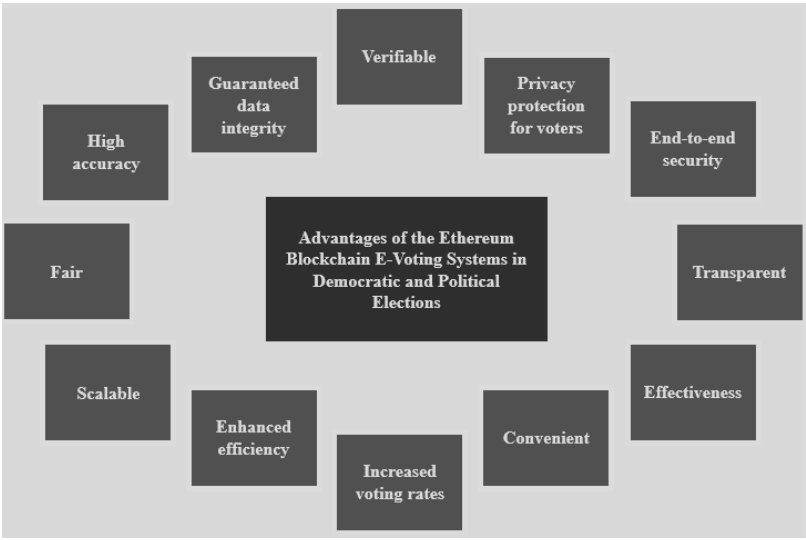
Several studies have highlighted multiple advantages of employing Ethereum blockchain e-voting systems in elections (Table 1). Among the greatest benefits include guaranteed data integrity and verifiability (Panja & Roy, 2021) which is essential in making sure that the sanctity of the election process is protected at all times. On top of that, these e-voting systems offer a high degree of privacy protection for voters (Alshehri et al., 2023), with enhanced security (Krishnamurthy et al., 2020; Abuidris et al., 2021; Panja & Roy, 2021; Alshehri et al., 2023) to prevent ballot stuffing attacks (Panja & Roy, 2021), and vote manipulation (Krishnamurthy et al., 2020) from

occurring. Through blockchain technology, its transparency features (Krishnamurthy et al., 2020) can ensure that the voting procedure conducted is transparent and auditable by all relevant political parties. The convenience of deploying these e-voting systems (Krishnamurthy et al., 2020) can help to increase voter turnout (Krishnamurthy et al., 2020) efficiency, and effectiveness (Abuidris et al., 2021; Panja and Roy, 2021) since voters can cast their ballots from anywhere. Moreover, they are scalable (Abuidris et al., 2021; Alshehri et al., 2023) and can effectively handle a huge number of votes. To add on, elections that are inclusive, fair (Alshehri et al., 2023), and accurate (Abuidris et al., 2021) can be made possible by the implementation of Ethereum blockchain e-voting. Figure 2 illustrates the various advantages that the Ethereum blockchain e-voting systems have to offer during political elections.

While Ethereum blockchain-based e-voting systems offer many advantages in political elections, several challenges may also arise. Adoption of the e-voting system is one of the main obstacles identified by all the analyzed studies (Krishnamurthy et al., 2020; Abuidris et al., 2021; Panja and Roy, 2021; Alshehri et al., 2023). Another hurdle lies in the sophistication and complexity of the blockchain technology itself (Abuidris et al., 2021; Panja and Roy, 2021; Alshehri et al., 2023), which can make comprehending and operating such a high-tech system challenging. Moreover, scalability can present a further challenge (Krishnamurthy et al., 2020; Alshehri et al., 2023), particularly during instances of high voting activity. Furthermore, the overall performance of the e-voting system is of utmost importance (Abuidris et al., 2021); it must maintain operational efficiency when managing concurrent votes on election day. Ultimately, privacy and confidentiality continue to be critical concerns for anyone involved in the election process (Krishnamurthy et al., 2020; Panja and Roy, 2021). Figure 3 highlights the challenges that may be faced when implementing Ethereum blockchain e-voting systems.

Figure 2

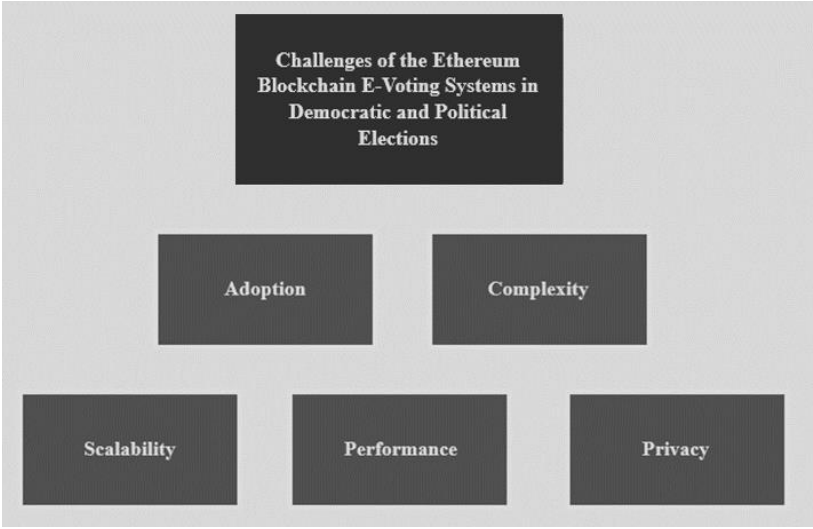
Advantages of the Ethereum Blockchain E-Voting Systems in Democratic and Political Elections



The study of Alshehri et al. (2023) emphasized the use of an Ethereum-based voting system, which employs score voting, enabling voters to assign scores at a certain range to candidates. In this architecture system, the votes are encrypted before being uploaded to the blockchain to promote fairness in the election process. Typically, the vote will only be approved and added to the blockchain once the voters validate that their submitted scores are within the predetermined range. Through comprehensive experiments, the results signify that the system exhibits effective performance with the capability to process and support up to 10,000 transactions concurrently. The Ethereum blockchain e-voting system as laid out in Abuidris et al. (2021) focuses on a comparative analysis between the classical blockchain method and the proposed e-voting hybrid blockchain approach. As demonstrated by the performance evaluation, it is confirmed that the proposed hybrid blockchain has higher effectiveness with lower attacker success probability compared to that of the classical blockchain. On top of that, the hybrid system, composed of Ethereum serving as the upper chain, functions to store distinct blockchain states across all voters when those voters have established a consensus on the transactions.

Figure 3

Challenges of the Ethereum Blockchain E-Voting Systems in Democratic and Political Elections



Based on Krishnamurthy et al. (2020), several common factors contributing to low voter turnout include standing in long queues and the risk of poll violence. Consequently, many regular citizens choose to opt out of voting altogether to avoid the resulting chaos. The proposed blockchain system utilizes IoT devices, with authentication and verification being conducted by considering several evaluation factors, such as resource consumption, response time, and request processing. As presented in the findings of Panja and Roy (2021), the Ethereum blockchain approach in e-voting systems incorporates a cryptographic technique crucial for confidential ballot elections and ensures that each vote is end-to-end verifiable. Leveraging cutting-edge cryptographic techniques can help reinforce voting safety, secure the electoral process, and defend against cyberattacks, including ballot stuffing. The system also employs non-interactive zero-knowledge proofs and multi-party computation, which ensure that voters' privacy is preserved, as their identity or any other data about their vote is not disclosed. The final tally is published while keeping the machine tallies concealed.

Table 1

Articles Related to Ethereum Blockchain-Based E-Voting for Analysis

Technological Approaches	Advantages	Challenges
➢ Blockchain-based privacy-preserving score voting system (Alshehri et al., 2023)	➢ End-to-end security (Krishnamurthy et al., 2020; Panja & Roy, 2021; Abuidris et al., 2021; Alshehri et al., 2023)	➢ Adoption (Krishnamurthy et al., 2020; Abuidris et al., 2021; Panja & Roy, 2021; Alshehri et al., 2023)
➢ Hybrid Proof of Credibility and Proof of Stake (PSC)-blockchain method (Abuidris et al., 2021)	➢ Scalability (Abuidris et al., 2021; Alshehri et al., 2023)	➢ Complexity (Abuidris et al., 2021; Panja & Roy, 2021; Alshehri et al., 2023)
➢ Blockchain-enabled IoT e-voting system (Krishnamurthy et al., 2020)	➢ Fairness (Alshehri et al., 2023),	➢ Scalability (Krishnamurthy et al., 2020; Alshehri et al., 2023),
➢ Cryptographically secure end-to-end verifiable blockchain e-voting system (Panja & Roy, 2021)	➢ Privacy protection for voters (Alshehri et al., 2023)	➢ Performance (Abuidris et al., 2021)
	➢ High accuracy (Abuidris et al., 2021)	➢ Privacy (Krishnamurthy et al., 2020; Panja & Roy, 2021)
	➢ Increased efficiency and effectiveness (Abuidris et al., 2021; Panja & Roy, 2021)	
	➢ Increased voting rates (Krishnamurthy et al., 2020)	
	➢ Transparency (Krishnamurthy et al., 2020)	
	➢ Prevention of vote manipulation (Krishnamurthy et al., 2020)	
	➢ Convenience of registering votes (Krishnamurthy et al., 2020)	
	➢ Prevention of ballot stuffing attacks (Panja & Roy, 2021)	
	➢ Verifiability (Panja & Roy, 2021)	
	➢ Ensured integrity in tallying processes (Panja & Roy, 2021)	

DISCUSSION

Advantages of the Ethereum Blockchain E-Voting Systems for Democratic and Political Elections

Ethereum approach to e-voting, featuring blockchain technology, can indeed offer a decentralized, trustless architecture. This system enforces one vote per mobile phone number for each poll, thereby making sure that there is no duplication in votes and preserving the privacy of the voter. Additionally, there is no need for a third-party server because users are verified using their mobile phone numbers. The e-voting system can achieve greater inclusivity and accessibility without the need for electoral intermediaries, thereby facilitating participation in the electoral process. This stands in contrast to traditional voting methods, which may pose difficulties to voters, especially those residing in remote areas or those with mobility impairments. This approach is not only user-friendly but also helps to reduce the overall logistical expenses because it eliminates the need for scaling up across several polling centers, which certainly increases the cost of running elections, especially when factoring in that there are a few each year, requiring a repeat setup for every election. In addition, the financial viability can be improved in the long run, as the tendency for errors and fraud is reduced by the transparency of blockchain technology.

Per the proposed method mentioned by Alshehri et al. (2023), it typically emphasizes scalability, which is vital when dealing with many voters, as often seen during national elections such as presidential elections. In such elections, it is not surprising that the total number of participating voters could reach up to millions or even tens of millions. Hence, with this remarkable characteristic of the Ethereum blockchain e-voting system, even during peak usage, the system can remain efficient. This approach of e-voting also proves flexibility since it extends beyond government use to enable opposition political parties to adopt it. This ultimately opens up new avenues to enhance democratic practices and streamline the voting process when conducting referendums and elections. Indeed, scalability is a critical component of an effective electoral process; it allows the system to manage a large volume of voters and transactions without degrading the performance.

The outcome of the study of Abuidris et al. (2021) may imply that attackers would have difficulties in executing malicious activities that

could compromise the accuracy of the voting process via the use of an e-voting hybrid blockchain. The blockchain technology that encrypts votes can certainly assure their legitimacy and aid in the prevention of tampering. In this respect, every vote is protected against forgery. Furthermore, it helps to deter issues like vote manipulation and eavesdropping. With these measures in place, a secure voting experience can be created where trust is instilled among voters. To add on, the smart contracts deployed on the Ethereum blockchain play a crucial role in ensuring the accuracy of the ballot results, thus embedding trust in the public bulletin board via a secure computing environment. Any inaccuracies with votes can potentially undermine democracy. Hence, the secure hybrid blockchain system ensures accuracy while also protecting the rights of the voters.

When examining the work of Krishnamurthy et al. (2020), leveraging the blockchain-powered e-voting system can enable voters to register and submit their votes hassle-free using their cell phones. With such convenience features of e-voting, more voters will likely engage in the voting process which, eventually, leads to a significant increase in voting rates and improves the response times among citizens. A more democratic and fair result in political elections is reflected in the greater inclusivity of the entire population. During times like pandemics such as COVID-19, this e-voting system is particularly useful in preventing the spread of viruses associated with in-person voting. In this regard, voters can still engage in the democratic voting process while keeping themselves healthy.

By assessing the study performed by Panja and Roy (2021), it is believed that the credibility of the election results can be trusted since the system can recognize and thwart attempts to create and submit fraudulent ballots or fake votes. Maintaining the integrity of any political elections is of paramount importance. In general, the election results are a true reflection of decisions that the electorate made. Any compromise in the integrity of democratic processes can erode the foundation of democracy. Therefore, upholding election integrity is fundamental for the preservation of democracy as a whole.

Challenges of the Ethereum Blockchain E-Voting Systems for Democratic and Political Elections

Several challenges may stand in the way of the implementation of the Ethereum blockchain-based e-voting system in political elections. In

the aspect of adoption, it can be challenging to persuade governments and all political parties to adopt a technology that is new and unfamiliar, as they might have become very accustomed to old practices. The complexity of setting up and running such an e-voting system could yet be another challenge because extensive testing and validation are required before it is ready to be integrated into the existing electoral frameworks. Complexities arise, particularly in circumstances where large-scale elections are involved, since there will be a call for robust resources and infrastructure to accommodate more candidates and voters. Moreover, it is essential to ensure that the e-voting system's speed and performance are not compromised, even when there is a high volume of votes that need to be managed at a time. During the voting process, maintaining privacy to ensure that the anonymity of voters is protected could still be a concern for some voters. Therefore, to deploy this Ethereum blockchain e-voting approach successfully, these challenges are some of the critical factors that need to be considered carefully.

Future Innovations of the Ethereum Blockchain E-Voting Systems for Democratic and Political Elections

For political elections, some of the future advancements that the Ethereum blockchain e-voting systems can concentrate on may include accountability, efficiency, enhanced security, and reliability**.** Since most Ethereum blockchain itself is not natively integrated with the Internet of Things (IoT) as observed in the existing studies (Panja & Roy, 2021; Abuidris et al., 2021; Alshehri et al., 2023), it is recommended to create an application that uses both of these technologies. Furthermore, merging of Ethereum with other advanced technologies such as artificial intelligence (AI) and big analytics can further benefit the political voting process in various ways, whether it is dedicated to election officials, government agencies, or the voters. Ethereum blockchain e-voting systems can benefit from using facial recognition technology as an authentication method during login as it is recognized as an inclusive approach for all voters, unlike conventional password verification. Table 2 lists the possible future innovations that can be integrated into the present Ethereum blockchain e-voting systems.

Table 2

Future Innovations of the Ethereum Blockchain-Based E-Voting Systems

Integration of IoT	Artificial Intelligence and Big Analytics	Facial Recognition Technology
➢ Track voter traffic and functionality status of the e-voting machines ➢ Monitor the entire voting process in real-time ➢ Ensure accountability	➢ Better structure and allocate resources for the upcoming elections ➢ Easily predict voter turnout and behavior through historical polling statistics ➢ Voter personalization experience ➢ Offer details about elected representatives, politicians, or candidates that align with the voters' interests ➢ Better voter engagement Increased election participation Further increase efficiency	➢ A more secure and convenient alternative to conventional password verification ➢ No memorization involved ➢ Rapid identity authentication process ➢ Not easily hijacked ➢ Reduce unauthorized access ➢ Enhanced security and reliability

Impact of Decentralized Electronic Voting Systems on Democracies

Such decentralized e-voting systems, built on the Ethereum blockchain, demonstrate democratic value over a range of election cycles, be it federal or general. This system can indeed be beneficial to various stakeholders, including electoral officials, politicians, and voters across different political parties, whether they are part of coalition parties or opposition parties. Overall, the use of decentralized e-voting systems holds promise for strengthening democratic procedures in the long run.

CONCLUSION

This systematic review offers a glimpse into the future of political elections by uncovering the diverse advantages that Ethereum blockchain-based e-voting systems have to offer. Overall, these systems ensure integrity, enhance security, and provide verifiability. With great potential, this approach can serve as an alternative to conventional election methods, which are prone to vote manipulation and errors. Moreover, they illuminate the potential of revolutionizing the democratic electoral process by ushering in transparent elections through an immutable record of ballots. Looking ahead, a more robust and reliable blockchain-based e-voting system could be built upon, with AI and big data analytics as future innovations. In modern democracies, this prompts a call to action and instills hope for a more inclusive e-voting future.

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REFERENCES

Abuidris, Y., Kumar, R., Yang, T., & Onginjo, J. (2021). Secure large-scale e-voting system based on blockchain contract using a hybrid consensus model combined with sharding. *Electronics and Telecommunications Research Institute Journal, 43*(2), 357-370. https://doi.org/10.4218/etrij.2019-0362

Adiputra, C. K., Hjort, R., & Sato, H. (2018). A proposal of blockchain-based electronic voting system. *2018 Second World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4)*, *2018*, 22-27. https://doi.org/10.1109/WorldS4.2018.8611593

Alshehri, A., Baza, M., Srivastava, G., Rajeh, W., Alrowaily, M., & Almusali, M. (2023). Privacy-preserving e-voting system supporting score voting using blockchain. *Applied Sciences, 13*(2), 1-18. https://doi.org/10.3390/app13021096

Avgerou, C. (2013). Explaining trust in IT-mediated elections: A case study of e-voting in Brazil. *Journal of the Association for Information Systems*, *14*(8), 420-451. https://doi.org/10.17705/1jais.00340

Çabuk, U. C., Adıgüzel, E., & Karaarslan, E. (2018). A survey on feasibility and suitability of blockchain techniques for the e-voting systems. *International Journal of Advanced Research in Computer and Communication Engineering*, *7*(3), 124-134. https://doi.org/10.17148/ijarcce.2018.7324

Heiberg, S., & Willemson, J. (2015). Verifiable internet voting in Estonia. *2014 6th International Conference on Electronic Voting: Verifying the Vote*, 1-7. https://doi.org/10.1109/EVOTE.2014.7001135

Ibrahim, M., Ravindran, K., Lee, H., Farooqui, O., & Mahmoud, Q. H. (2021). ElectionBlock: An electronic voting system using blockchain and fingerprint authentication. *Proceedings - 2021 IEEE 18th International Conference on Software Architecture Companion, ICSA-C 2021*, 123-129. https://doi.org/10.1109/ICSA-C52384.2021.00033

Khan, K. M., Arshad, J., & Khan, M. M. (2019). Investigating performance constraints for blockchain based secure e-voting system. *Future Generation Computer Systems*, *105*, 13-26. https://doi.org/10.1016/j.future.2019.11.005

Koç, A. K., Yavuz, E., Çabuk, U. C., & Dalkiliç, G. (2018). Towards secure e-voting using Ethereum blockchain. *6th International Symposium on Digital Forensic and Security, ISDFS 2018*, 143-148. https://doi.org/10.1109/ISDFS.2018.8355340

Krishnamurthy, R., Rathee, G., & Jaglan, N. (2020). An enhanced security mechanism through blockchain for E-polling/counting process using IoT devices. *Wireless Networks*, *26*(4), 2391-2402. https://doi.org/10.1007/s11276-019-02112-5

Malkawi, M., Yaseen, M. B., & Habeebalah, D. (2023). Ethereum blockchain based e-voting system for Jordan Parliament Elections. *Applied Mathematics and Information Sciences*, *17*(2), 233-241. https://doi.org/10.18576/amis/170206

Nicolau, J. (2015). Impact of electronic voting machines on blank votes and null votes in Brazilian elections in 1998. *Brazilian Political Science Review*, *9*(3), 3-20. https://doi.org/10.1590/1981-38212015000300017

Panja, S., & Roy, B. (2021). A secure end-to-end verifiable e-voting system using blockchain and cloud server. *Journal of Information Security and Applications*, *59,* 1-25. https://doi.org/10.1016/j.jisa.2021.102815