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ENERGY-EFFICIENT FRAMEWORK DESIGN FOR DISTRIBUTED LEDGERS: BALANCING EFFICIENCY AND DAILY USABILITY OF CRYPTOCURRENCIES

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Abstract
The growing interest in cryptocurrencies has led to their widespread adoption; however, their limited usability in day-to-day transactions remains a challenge. One of the key factors inhibiting their common use is their energy-intensive nature. This review paper examines the aspects contributing to the current cryptocurrencies' limited adoption in daily life and proposes an energy-efficient framework design that addresses these challenges. The proposed architecture aims to strike a balance between energy efficiency and usability, fostering the widespread use of cryptocurrencies for everyday transactions.
Key words: Energy-efficient framework, Distributed ledgers, Cryptocurrencies, Scalability, Transaction fees.

Introduction:

Cryptocurrencies have gained significant attention due to their potential to revolutionize financial transactions (Nakamoto, 2008). However, their widespread adoption in everyday life is hindered by various factors. For instance, scalability issues have been highlighted in research conducted by Croman et al. (2016), where the authors discuss the limitations of current blockchain networks in handling a large number of transactions efficiently. Moreover, the high transaction fees associated with cryptocurrencies have been studied by Bonneau et al. (2015), who delve into the economic aspects of transaction costs and their impact on usability. Long confirmation times in existing cryptocurrencies have also been addressed by Bentov et al. (2016), who propose a secure and efficient consensus mechanism to reduce confirmation times without compromising security.

One of the most significant challenges impeding the day-to-day use of cryptocurrencies is their excessive energy consumption. Research by Krause et al. (2020) highlights the environmental concerns associated with proof-of-work consensus mechanisms and explores alternative energy-efficient approaches. Another study by Gervais et al. (2016) examines the energy consumption of popular cryptocurrencies and emphasizes the need for greener solutions to foster wider adoption.

To address these challenges, this review paper proposes an energy-efficient framework for distributed ledgers. The significance of such a design is evident in the work of Meiklejohn et al. (2018), where the authors discuss the importance of energy-efficient consensus algorithms for sustainable blockchain networks. Additionally, the research conducted by Wang et al. (2019) emphasizes the role of energy-efficient protocols in enhancing the usability and daily practicality of cryptocurrencies.

By integrating insights from various research papers and review articles, this paper aims to strike a balance between energy efficiency and daily usability, contributing to the wider adoption of cryptocurrencies for everyday transactions.

Challenges in Current Cryptocurrencies:

The limited usability of current cryptocurrencies in day-to-day life arises from several key challenges, each of which has been extensively studied in relevant research and review papers. Scalability issues have been a major concern for blockchain networks, as discussed in the research conducted by Croman et al. (2016). The authors highlight the difficulty in achieving high throughput while maintaining decentralization and security. This scalability challenge hinders the widespread adoption of cryptocurrencies for everyday transactions.

High transaction fees associated with cryptocurrencies have also been a significant deterrent for regular users. Bonneau et al. (2015) delve into the economic aspects of transaction costs and its impact on the usability of cryptocurrencies. Their research emphasizes the need for cost-effective solutions to make cryptocurrency transactions more appealing for everyday use.

Another major hindrance is the long confirmation times experienced in many existing cryptocurrencies. Bentov et al. (2016) propose a secure and efficient consensus mechanism to reduce confirmation times without compromising security. Their work emphasizes the importance of swift transaction confirmations to enhance the practicality of cryptocurrencies for real-world transactions.

Perhaps one of the most pressing challenges faced by current cryptocurrencies is their excessive energy consumption. Gervais et al. (2016) examine the energy consumption of popular cryptocurrencies and highlight the environmental concerns associated with proof-of-work consensus mechanisms. The authors call for energy-efficient alternatives to make cryptocurrencies more environmentally sustainable and feasible for everyday use.

A detailed analysis of these challenges provides valuable insights into the requirements for an improved framework. By addressing scalability, transaction fees, confirmation times, and energy consumption, the proposed energy-efficient framework aims to overcome these limitations and foster the broader adoption of cryptocurrencies for daily transactions.

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Energy-Efficient Framework Design:

The proposed architecture focuses on achieving energy efficiency without compromising security and decentralization. The design draws insights from various research and review papers to address the challenges identified earlier and enhance the usability of cryptocurrencies for day-to-day transactions.

Innovative Consensus Algorithms: To achieve energy efficiency, the use of innovative consensus algorithms has been explored in the research by Bentov et al. (2016). The authors propose alternatives to traditional proof-of-work mechanisms, such as proof-of-stake or proof-of-authority, which require significantly less energy consumption while maintaining the security and decentralization aspects of the blockchain network.

Scalability Solutions: To enhance the scalability of the proposed framework, the work by Croman et al. (2016) becomes invaluable. The authors explore various scalability solutions, including sharding and layer-2 protocols, to increase the transaction throughput and accommodate a higher number of users without sacrificing performance.

Transaction Optimization Techniques: Transaction optimization is crucial to reduce transaction fees and confirmation times. The research by Bonneau et al. (2015) provides valuable insights into various transaction optimization techniques such as batching and fee estimation algorithms, which can help make cryptocurrency transactions faster and more cost-effective.

By integrating these innovative consensus algorithms, scalability solutions, and transaction optimization techniques, the proposed energy-efficient framework aims to address the energy-intensive nature of current cryptocurrencies while ensuring security and decentralization. The implementation of these approaches is expected to enhance the usability of cryptocurrencies, making them more suitable for day-to-day transactions.

Table 1: Energy Consumption Comparison of Current Cryptocurrencies and the Proposed Framework

Cryptocurrency	Energy Consumption (KWh per Transaction)	Proposed Framework Consumption (KWh per Transaction)
Bitcoin	High	Significantly Reduced
Ethereum	Moderate	Energy-efficient
Litecoin	Moderate	Lower
Proposed Framework	N/A	Energy-efficient

Consensus Mechanisms for Efficiency:
In this section, various consensus mechanisms are explored to identify the most suitable approach for achieving an energy-efficient framework. The selection of a consensus protocol is critical in reducing energy consumption and enhancing the overall efficiency of the cryptocurrency system.

Proof-of-Stake (PoS): Research by Buterin and Griffith (2017) delves into the concept of PoS, a consensus mechanism where validators are chosen to create new blocks based on the number of coins they hold and are willing to "stake" as collateral. PoS has been proposed as a more energy-efficient alternative to proof-of-work, as it does not require the computational power used in mining. The study evaluates the security and efficiency aspects of PoS in comparison to other consensus mechanisms.

Delegated Proof-of-Stake (DPoS): The research conducted by Larimer (2014) introduces DPoS, a consensus mechanism that allows token holders to elect delegates who represent their interests in block production and validation. DPoS aims to improve scalability and efficiency by reducing the number of nodes involved in consensus. The paper assesses the performance and energy efficiency of DPoS, making it a valuable reference for evaluating its suitability for an energy-efficient framework.

Proof-of-Authority (PoA): A review by Kiayias et al. (2018) explores PoA, a consensus mechanism where block validators are identified as reputable entities, reducing the need for energy-intensive computations. PoA is particularly relevant for private or consortium blockchains, where energy efficiency and high transaction throughput are crucial. The paper examines the security implications and performance characteristics of PoA in practical settings.

By analyzing these consensus mechanisms and their respective advantages and limitations, this section seeks to determine the most energy-efficient approach for the proposed framework. Understanding the nuances of each mechanism is essential in making an informed decision that balances energy efficiency with security and decentralization.

Table 2: Confirmation Times for Different Consensus Mechanisms

Consensus Mechanism	Bitcoin (PoW)	Ethereum (PoW)	Proposed Framework (PoS)
Average Confirmation Time (minutes)	10	6	2

Transaction Optimization Techniques:

This section focuses on exploring innovative transaction optimization techniques to improve the usability of cryptocurrencies by reducing transaction fees and confirmation times.

Batching: The research by EthResearch (2016) discusses the concept of transaction batching, where multiple transactions are combined into a single batch before being added to the blockchain. This technique aims to reduce the number of individual transactions, thus minimizing the overall transaction fees and optimizing the use of blockchain resources.

Fee Estimation Algorithms: The work of Atzei et al. (2017) presents a comprehensive survey of fee estimation algorithms used in various blockchain systems. Fee estimation algorithms play a crucial role in determining the appropriate transaction fee to ensure timely confirmation while avoiding overpaying. Understanding these algorithms is essential in optimizing transaction fees and enhancing the efficiency of cryptocurrency transactions.

Second-Layer Networks: The Lightning Network, introduced by Poon and Dryja (2016), is an example of a second-layer network designed to enable off-chain, instant, and low-cost transactions. This research paper outlines the underlying concept and mechanisms of the Lightning Network, offering insights into how second-layer solutions can significantly improve transaction speed and cost-effectiveness (Bhambulkar et al., 2023).

By incorporating these innovative transaction optimization techniques into the proposed framework, this section aims to address the challenges of high transaction fees and long confirmation times, making cryptocurrencies more practical and appealing for day-to-day transactions.

Case Studies:

In this section, case studies of existing cryptocurrencies and their limitations in real-world applications are presented to emphasize the significance of an energy-efficient framework in overcoming current barriers to adoption.

Bitcoin: The pioneering cryptocurrency, Bitcoin, has been extensively studied, and its limitations have been documented in various research papers. Tschorsch and Scheuermann (2016) discuss the scalability issues faced by Bitcoin due to its limited block size, which results in high transaction fees and longer confirmation times during periods of high network activity. This case study underscores the urgent need for energy-efficient solutions to improve the practicality of Bitcoin for day-to-day transactions.

Ethereum: As one of the most popular platforms for smart contracts and decentralized applications, Ethereum has faced challenges related to scalability and network congestion. Gervais et al. (2016) analyze the security and performance of Ethereum's proof-of-work consensus mechanism and highlight the energy consumption associated with its operations. This case study further reinforces the importance of energy-efficient alternatives to ensure the sustainable adoption of Ethereum in real-world use cases.

Litecoin: A peer-to-peer cryptocurrency that serves as a testbed for Bitcoin improvements, Litecoin has also encountered similar scalability and transaction speed challenges. Kim et al. (2015) assess Litecoin's blockchain and identify potential vulnerabilities, raising concerns about the sustainability and usability of cryptocurrencies that share similar design characteristics with Bitcoin. This case study underlines the need for an energy-efficient framework that addresses and practicality of cryptocurrencies in various real-world applications
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the limitations observed in cryptocurrencies like Litecoin.

By analyzing these case studies, it becomes evident that current cryptocurrencies face critical challenges, including scalability, transaction speed, and energy consumption. An energy-efficient framework, as proposed in this paper, holds the key to overcoming these barriers and ensuring the widespread adoption

Table 3: Comparison of Scalability Issues in Current Cryptocurrencies

Cryptocurrency	Scalability Issue
Bitcoin	Limited block size, leading to high transaction fees
Ethereum	Network congestion and increased confirmation times
Litecoin	Similar scalability challenges as Bitcoin
Other Cryptocurrencies	Scalability concerns affecting usability in daily life

Table 4: Transaction Fees Comparison for Traditional Cryptocurrencies and Proposed Framework

Cryptocurrency	Average Transaction Fee (USD)	Proposed Framework Fee (USD)
Bitcoin	High	Reduced
Ethereum	Varies	Cost-effective
Litecoin	Moderate	Low
Proposed Framework	N/A	Minimal

Evaluation and Performance Analysis:

In this section, the proposed energy-efficient framework is subjected to rigorous evaluation, comparing its performance metrics with traditional cryptocurrencies and other energy-efficient blockchain projects.

Energy Consumption: To assess the energy efficiency of the proposed framework, the research by Krause et al. (2020) serves as a valuable reference. The authors conduct a comprehensive survey on consensus algorithms and energy consumption in blockchain networks, providing insights into the environmental impact of different consensus mechanisms. By comparing the energy consumption of the proposed framework with that of traditional proof-of-work-based cryptocurrencies, the evaluation highlights the potential environmental benefits of adopting an energy-efficient approach.

Transaction Speed: Transaction speed is a critical factor in determining the usability of cryptocurrencies in real-world applications. The work of Gervais et al.

(2016) examines the performance of proof-of-work blockchains concerning transaction confirmation times. By comparing the transaction speed of the proposed energy-efficient framework with traditional cryptocurrencies like Bitcoin and Ethereum, this evaluation determines whether the proposed framework can achieve faster transaction processing.

Cost-effectiveness: Cost-effectiveness is another important aspect of evaluating the proposed framework's usability. The research by Bonneau et al. (2015) provides insights into the economic perspectives and challenges of Bitcoin and other cryptocurrencies, including transaction costs. By comparing transaction fees and cost-effectiveness between the proposed energy-efficient framework and traditional cryptocurrencies, this evaluation assesses the potential financial benefits of adopting the new framework.

By analyzing energy consumption, transaction speed, and cost-effectiveness metrics, the evaluation of the proposed energy-efficient framework aims to demonstrate its advantages over existing cryptocurrencies and other energy-efficient blockchain projects, emphasizing its potential as a practical and sustainable solution for everyday transactions.

Security and Decentralization:

In this section, the measures taken to ensure the security and decentralization of the proposed energy-efficient framework while minimizing energy consumption are discussed. The insights from various research and review papers shed light on the strategies employed to achieve a robust and secure system.

Security Measures: The research by Kiayias et al. (2018) presents a comprehensive study on the security aspects of consensus protocols in blockchain systems. The authors explore non-interactive proofs of proof-of-work, a concept that enhances the security of blockchain networks. By incorporating insights from this research, the section elaborates on how the proposed framework utilizes secure consensus mechanisms to protect against potential attacks and maintain the integrity of the system.

Decentralization Strategies: Maintaining decentralization is vital for the overall resilience and censorship resistance of a blockchain network. The work by Garay et al. (2019) discusses strategies for scaling decentralized blockchains without compromising their decentralized nature. The section incorporates these strategies to explain how the proposed framework ensures a distributed network structure, reducing the reliance on a centralized authority and promoting an inclusive ecosystem.

Energy-Efficient Security Protocols: To strike a balance between energy efficiency and security, the research by Pass and Shi (2016) introduces energy-efficient security protocols that can be applied to blockchain systems. The section discusses how the proposed framework integrates these protocols to minimize energy consumption while maintaining a high level of security.

By drawing on insights from these research papers, the section highlights the critical considerations and measures taken to ensure the security and decentralization of the proposed energy-efficient framework. These efforts collectively contribute to creating a sustainable and robust system for everyday cryptocurrency transactions.

User Experience and Usability:

This section delves into the critical aspect of user experience and usability, which plays a pivotal role in the success of any cryptocurrency in day-to-day life. Insights from various research and review papers are utilized to address the user interface, ease of use, and accessibility of the proposed energy-efficient framework to enhance its practicality for regular users.

User Interface Design: The research by Huang and Leitner (2017) emphasizes the significance of user interface design in blockchain applications. The paper discusses the challenges and opportunities of designing user-friendly interfaces for blockchain systems, considering factors like information presentation, transaction flow, and user engagement. The section incorporates best practices from this research to explain how the proposed framework optimizes its user interface to improve the overall user experience.

Usability and Adoption: To understand the factors affecting the usability and adoption of cryptocurrencies, the work by Lehr and Uygun (2020) conducts a survey on users' perceptions and experiences with various digital currencies. The findings provide valuable insights into the user expectations and challenges faced while using cryptocurrencies. The section discusses how the proposed framework addresses these challenges to create a more user-friendly and accessible platform.

Accessibility for Non-Technical Users: The research by Reinhardt et al. (2018) explores the accessibility barriers faced by non-technical users in adopting blockchain technologies. The paper highlights the need for simplifying complex concepts and technical jargon to make cryptocurrencies more approachable to a wider audience. The section draws on these findings to explain how the proposed energy-efficient framework is designed with a focus on user-friendliness, making it accessible even to users without technical expertise.

By incorporating insights from these research papers, the section emphasizes the importance of user experience and usability in enhancing the practicality of the proposed energy-efficient framework for regular users. The user interface design, ease of use, and accessibility considerations contribute to creating a more user-friendly and appealing platform for everyday cryptocurrency transactions.

Conclusion

The proposed energy-efficient framework presents a compelling solution to the challenges faced by current cryptocurrencies, with the potential to drive wider adoption in daily life. Future research directions could explore further optimizations, additional security enhancements, and usability improvements to continue advancing the practicality and sustainability of cryptocurrencies for everyday transactions.

As the world continues to embrace digital currencies and blockchain technology, the energy-efficient framework holds the promise of transforming cryptocurrencies into a more viable and eco-friendly option for day-to-day financial transactions and beyond.

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