Deploying Energy-Efficient Blockchain Solutions in Cognitive Wireless Communication Networks (CWCNs)

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Abstract

Given the computational constraints of sensor devices and the critical importance of Cognitive Wireless Communication Networks (CWCNs), adopting traditional blockchain mechanisms proves impractical for CWCNs. Moreover, considering the paramount security and privacy concerns inherent in CWCNs, particularly in applications like ambient assisted living which directly impact human lives, blockchain emerges as a viable solution. However, adaptations are required to streamline the computation of Proof of Work (PoW), introducing a more straightforward approach. Hence, the fourth objective seeks to introduce an energy-efficient blockchain implementation tailored for CWCNs. This approach is meticulously designed to minimize energy consumption during computation, a critical consideration in the context of CWCNs. Notably, the implementation involves addressing the energy-intensive nature of blockchain through a simplified approach, particularly in the resource-intensive mining process. This strategic streamlining renders the blockchain solution energy-efficient, primarily concerning computation time. To demonstrate the viability of this approach, an energy-intensive blockchain model is deployed within a resource-limited CWCN, specifically catered to ambient assisted living applications with a focus on elderly care. The process involves the aggregation of physical environmental data using a single-board computer-based CWCN.

Keywords: CWCN Energy efficiency Blockchain Proof of work Computation time Resource-constrained

Introduction

In recent years, the convergence of wireless communication technologies and blockchain has opened up new avenues for innovation and transformation across various domains [1]. Cognitive Wireless Communication Networks (CWCNs) represent a paradigm shift in wireless communication, leveraging cognitive capabilities to optimize spectrum usage, enhance network performance [2], and enable

ISSN PRINT 2319 1775 Online 2320 7876

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dynamic adaptability [3]. As CWCNs find applications in critical areas such as ambient assisted living, where human lives are directly impacted, ensuring energy efficiency and security becomes paramount [4]. Traditional blockchain implementations, while powerful, often face challenges when integrated into resource-constrained environments like CWCNs [5]. The limited computation resources of sensor devices, coupled with the unique demands of CWCNs, necessitate innovative approaches to achieve the desired balance between energy efficiency and blockchain functionality [6]. This research addresses these challenges by presenting an energy-efficient blockchain implementation tailored specifically for CWCNs [7]. The overarching goal is to develop a solution that not only harnesses the benefits of blockchain, such as data immutability and transparency, but also optimizes energy consumption to align with the constraints of CWCNs [8]. In the context of security-sensitive applications like ambient assisted living, where the well-being of individuals is at stake, the need for an effective and efficient blockchain solution is of utmost importance [9]. Privacy concerns, data integrity, and real-time response are critical aspects that must be addressed to ensure the success and reliability of CWCNs in such applications [10]. This study explores the intricate interplay between energy efficiency, blockchain technology, and the unique requirements of CWCNs [11]. It aims to strike a delicate balance between ensuring robust security and optimizing energy consumption, all while contributing to the advancement of cognitive wireless communication in mission-critical scenarios [12]. Throughout this paper, we delve into the design, implementation, and evaluation of our proposed energy-efficient blockchain approach for CWCNs [13]. By combining insights from blockchain research, wireless communication, and energy optimization, we aim to provide a comprehensive solution that empowers CWCNs to deliver on their promises while minimizing the resource burden [14]. In the following sections, we delve into the methodology, technical details, and experimental results of our energy-efficient blockchain implementation in CWCNs [15]. Through this research, we aspire to pave the way for more sustainable, secure, and efficient cognitive wireless communication networks, opening doors to a multitude of innovative applications that have the potential to positively impact society.

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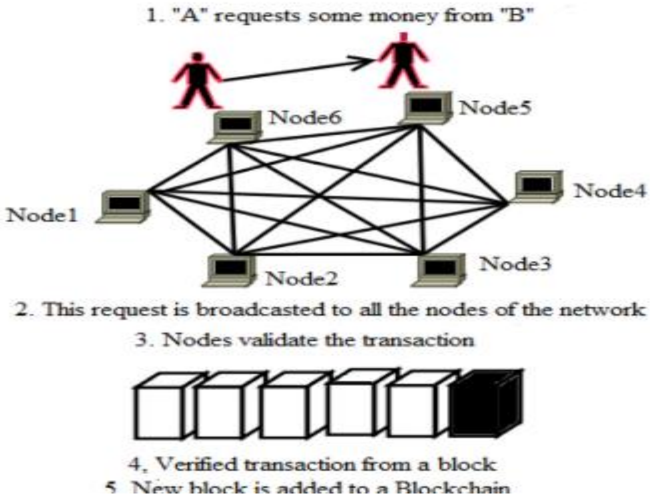

Analysis

Bitcoin is founded upon the principles of blockchain technology, which serves as a decentralized and permanent ledger of all historical transactions. The term "distributed" underscores the shared nature of this database, and each block within the blockchain is rigorously validated by consensus among a majority of participants. In essence, blockchain establishes a system of distributed consensus in the digital realm, akin to the role banks play as trustworthy intermediaries in the physical world (Figure 1).The blocks forming the blockchain are interconnected, with each block containing the hash of the preceding one. The initial block, referred to as the genesis block, is hardcoded. Typically, a block encompasses a sequence of transactions, the hash of the preceding block, and a nonce value that must be less than the current target τ. The target τ is regularly adjusted to modulate the level of complexity, impacting the computational effort required for Proof of Work (PoW) calculation (O'Dwyer and Malone, 2014). Complexity dictates the work needed to compute PoW, meaning that higher complexity necessitates more time for PoW calculation (Figure 2). Miners aim to calculate the nonce such that $H^{\cdot}(\beta \times \theta \times EH^{\cdot}) < \tau$, where β represents the transactions in the current block, θ is the nonce, $EH^{\cdot}$ denotes the hash of the previous block, and $H^{\cdot}$ is the cryptocurrency hash function (e.g., SHA256(SHA256(B)) for bitcoin). Blockchain's widespread adoption is attributed to its resilient approach against potential tampering. Unlike a single centralized copy held by an impartial observer like a bank, each participant in the system maintains their copy of the blockchain. Consequently, an attacker attempting to alter data within the blockchain would need to recalculate PoW for all blocks across all participants within the time frame of adding a new block to the authenticated blockchain. This task demands extensive computational resources, which often surpasses the value of the data stored on the blockchain.

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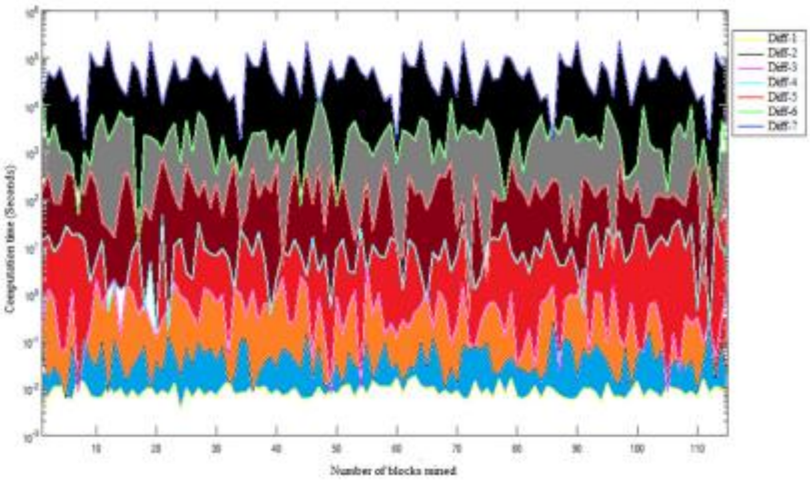

Fig. 2. Increasing level of difficulty over Computation time.

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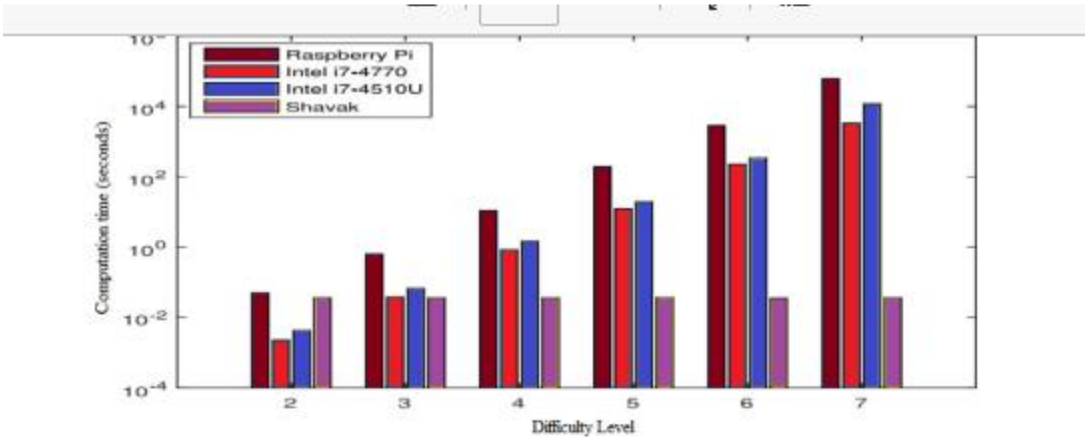
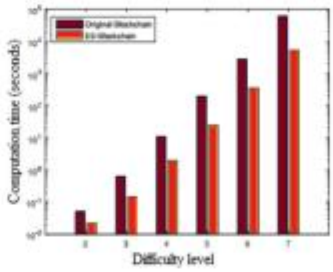
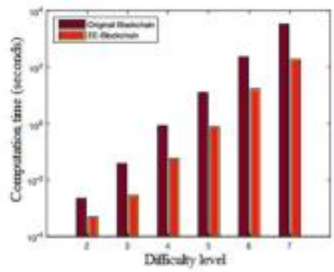


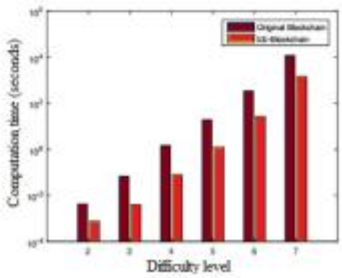
Fig. 4. Computation task of PoW on various machines.



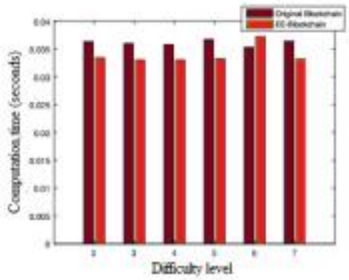
(a) for Raspberry Pi (single board computer)



(b) for i7-4770 (wired computer)



(c) for i7-4510U (battery powered computer)



(d) for Param shavak (the super computer)

Fig. 5. Energy efficient algorithm implementation on different machines.

Contribution: Addressing the significant carbon footprint of conventional blockchain implementation and recognizing the resource limitations of Cognitive Wireless Communication Networks (CWCNs), this paper examines the challenges and potential research avenues within this domain. Furthermore, the study introduces a simplified blockchain tailored for CWCNs, optimizing its applicability. This streamlined blockchain reduces the computational effort required for PoW calculation. The proposed application context revolves around environmental and atmospheric assisted living, focusing on elderly care in a spacious hall. The application collects physical parameters such as temperature, pressure, humidity, vibration, and light using a single board computer (Raspberry Pi). Specifically, the parameters

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temperature, pressure, and humidity are chosen with considerations for stable indoor air quality, sound sleep, and bedsores for bedridden elderly individuals.

Conclusion

Given the computational limitations inherent to Cognitive Wireless Communication Network (CWCN) devices and the pivotal significance of information validity and value within CWCN applications, a conventional blockchain implementation appears unattainable and unnecessary for this context. Furthermore, acknowledging the criticality of security and privacy in CWCN applications, particularly those with potential human life implications like ambient living or ambient assisted living, blockchain emerges as a fitting solution. However, it necessitates a streamlined approach to the computation of Proof of Work (PoW) to strike a balance. In response to these considerations, this study introduces a tailored and energy-efficient blockchain implementation designed specifically for CWCN applications. This novel approach demonstrates a 16% reduction in energy consumption with respect to computation time at varying levels of difficulty. Additionally, the research addresses specific issues raised within existing literature In essence, this work presents a comprehensive strategy to adapt blockchain technology for CWCN applications, aligning with their unique computational and security demands..

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