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Loreen Marie Powell

Michalina Hendon

Andrew Mangle

Hayden Wimmer

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Awareness of blockchain usage, structure, & generation of platform's energy consumption: Working towards a greener blockchain

Loreen M. Powell, *Bloomsburg University of Pennsylvania, lpowell@bloomu.edu*
Michalina Hendon, *University of the Cumberlands, michalina.hendon@ucumberlands.edu*
Andrew Mangle, *Bowie State University, amangle@bowiestate.edu*
Hayden Wimmer, *Georgia Southern University, hwimmer@georgiasouthern.edu*

Abstract

Blockchain is a disruptive information technology innovation with energy consumption. As more organizations look to implement or embrace blockchain innovations, research must focus on making the blockchain greener. This research explores the current innovative blockchain usage, structure, generations, and energy consumption. An energy consumption comparison for consensus protocols is provided along with a list of recommendations for implementing green blockchains. This paper provides a significant impact upon previous literature and aids organizations considering implementing a green blockchain.

Keywords: Blockchain, environmental sustainability, green IT, proof of work, proof of state, hash rate, energy consumption

Introduction

Blockchain, originally pioneered towards digital currency, has value-innovated properties such as decentralization, transparency, immutability, and security which make it an attractive innovative information technology (IT) for many organizations (Bai, Coreiro & Sarkis, 2020; Cao, Wang, Li, Gu, and Chen, 2019). As a result, blockchain has rapidly expanded beyond digital currency and into many additional uses in disparate areas including automotive, business, healthcare, operations, and supply chains (Queiroz &Wamba, 2019). Current blockchain innovations and initiatives are occurring world-wide among many developed and developing nations (Lim, Wang, Ren, & Lo, 2019; Kamath, 2018). While blockchain usage seems advantageous for organizations, there are noted disadvantages which include high development and implementation costs, technical risks, and ethical and environmental concerns (Bia et al. 2020; Bai & Sarkis, 2017; Paulavicius, Grigaitis, Igumenov, & Filatovas, 2019).

Research by Truby (2018) and Saberi, Kouhizadeh and Sarkis (2018) explain the blockchain process and how mining activities including key algorithms and computations require an excessive amount of energy which raises green IT use issues. As the global climate changes continue to occur, distributed energy resources (DERs), distributed Energy Storage Systems (DESS), and green IT deployment surface to the forefront of organization and government intervention within many countries. Specifically, many efforts are beginning to form regarding the development of green certificates and frameworks for blockchain.

However, the limited amount of reliable technology performance knowledge on newly formed blockchain operations and maintenance has been problematic (Zhao, Guo, & Chan, 2020). The goal of this paper is to explore blockchain usage, structure, generations, and energy consumption in an effort to provide a framework for a greener blockchain. This paper provides a significant impact upon previous literature and organizations considering a greener blockchain implementation. The remaining structure of this paper is as follows: Review of literature, purpose of the study, methodology, results, recommendations, and conclusion.

Review of literature

Blockchain

The core concept of blockchain can be found with the Lamport's Paxos protocol for a network of computers (Lamport, 1998). Additional early blockchain writings can be found in Bayer Haber and Stornetta (1993) and Haber and Stornetta (1990, 1997) where they proposed a digital ledger of signed documents with a chain using a group document and hash functions. However, it was the famous whitepaper titled "Bitcoin: A Peer-to-Peer Electronic Cash System" (Nakamoto, 2008) that forever altered, disrupted, and impacted the world after the 2008 global financial crises (Chuen, 2015). As a result, blockchain platforms began as a decentralized alternative to the existing financial system (Paulavicius et al, 2019). Today, blockchain is a trending technology in which many organizations are utilizing or have future plans to utilize.

Blockchain Usage
As shown in Figure 1, blockchain's decentralization, persistency, anonymity, and auditability are of interest to many large organizations (Zeng & Dai, 2018). Additionally, others believed that cybersecurity, accountability, transparency, and traceability have made blockchain very attractive and advantageous for organizations to utilize or explore (Lamas & Fernández-Caramés 2020). Currently, blockchain usage is rapidly becoming vast and wide (Powell, Swartz, Hendon, 2021). Ramaswamy (2020) stated that "Blockchain technology is most likely to change the next decade of business". Specifically, his research focused on the advantages of utilizing blockchain in small businesses and provides a framework for such adoption. Additionally, Daley (2020) reported 25 use cases of a wide variety of organizations utilizing blockchain. Similarly, Kot (2020) also provided examples of many organizations implementing blockchain. Table 1 provides a summary of several current use cases of blockchain.

Table 1. Blockchain Use Cases

Company / URL	Industry	Implementation
Burstiq / burstiq.com	Healthcare	Aiding the secure transfer of medical records through blockchain-based data solutions for the healthcare industry
MediaChain / mediachain.io	Music	Facilitating royalty negotiations and faster payments via a peer-to-peer decentralized database for sharing information
DHL / dhl.com	Logistics	Maintaining a digital ledger of shipping transactions to remove global supply chain complexities and facilitate greater trust and transparency
FollowMyVote / followmyvote.com	Government	Providing safety and confidence in voting through auditable blockchain and open-source technology
Maersk / maersk.com	Logistics	Analyzing supply chains and track goods to improve the cost of transportation by transparency of digital processes
STEEM steem.com	Social Media	Encouraging and incentivizing online content creation by providing immediate revenue streams.
Brave / brave.com	Digital Media	Supporting digital content and privacy-based ads through delivering a private advertising and creator reward platform.
MOBI / dlt.mobi	Transportation	Improving efficiency and effectiveness of transportation using blockchain and related technologies.

In addition to Table 1, other blockchain use cases can be found within the existing literature (Ismail & Materwala, 2019).

Blockchain Structure

Like the commonly known seven-layer Open System Interconnection (OSI) model which illustrated how information flows, blockchain can be described within a four-layer hierarchal structure. The structure consisted of an application layer, platform layer, distribution layer, and infrastructure layer in which each layer performs a particular function (Paulavicius et al, 2019). Figure 1 explains each layer's function and location within the infrastructure.

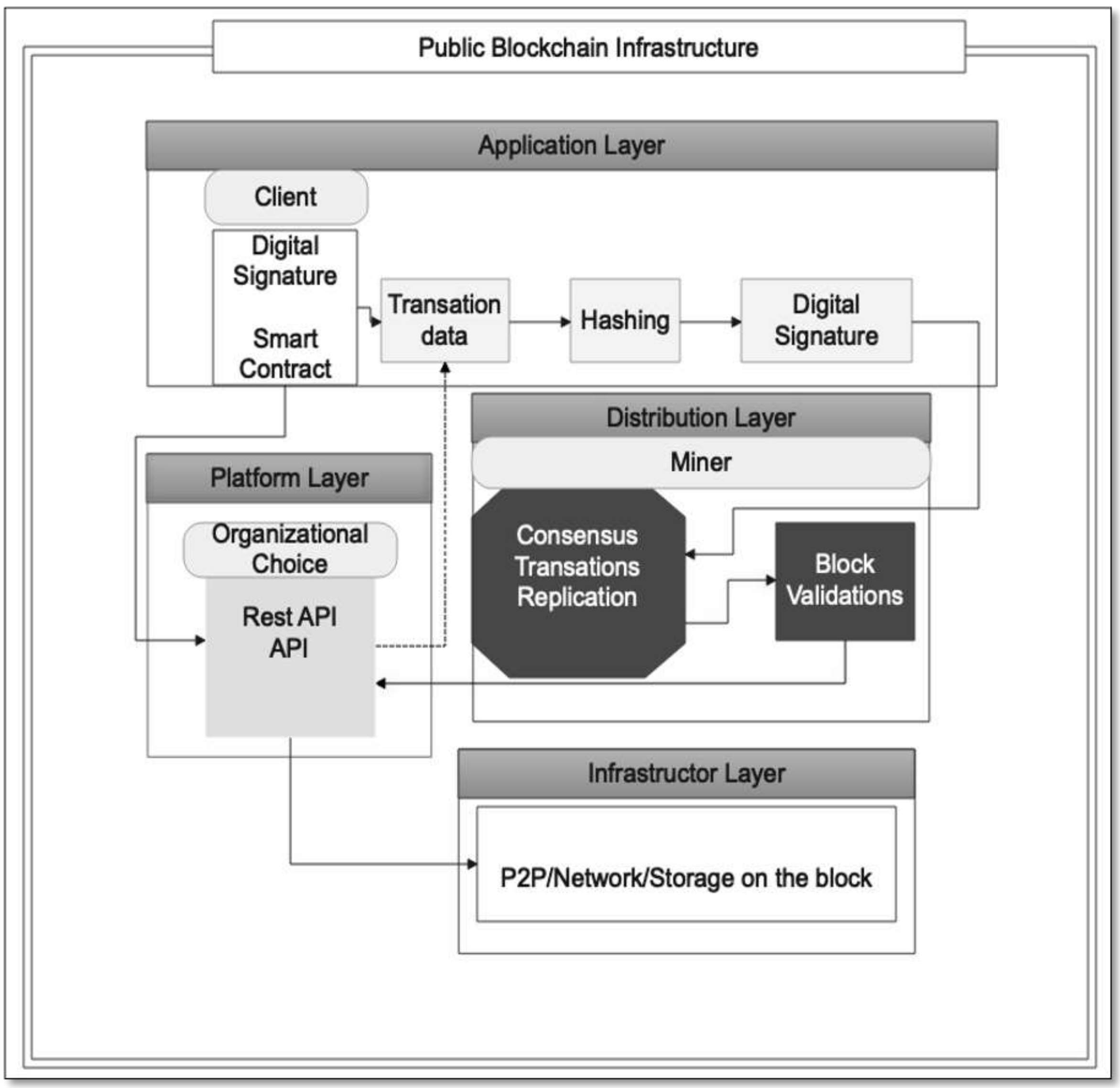

Figure 1. Public Blockchain Infrastructure with Layer Functions

Blockchain Platforms & Energy Consumption

Currently, there are two major types/generations of blockchain platforms. It is important to note the difference in generations is the consensus protocols used. Specifically, the first-generation platforms are Bitcoin and others that tend to focus on digital currency. This generation typically has excessive energy and carbon emission concerns. Specifically, the energy consumption which occurs within the mining process is extensive. The majority of digital currency platforms utilize a mining process with a Proof of Work (PoW) approach regarding immutability and validity (Paulavivius et al., 2019).

PoW is the consensus protocol for the mining of information on the chain. Miners utilize machines to perform the work regarding the immutability and validity of the information on each block forming the chain. Each block stores digital fragments of information such as date, time, and amount. The block also contains information regarding the transaction with a digital signature and a unique hash (Gulli, 2020). Miners choose computer equipment which allows for efficient mining of a highly complex mathematical equation to add the block onto the blockchain. It is in the process of solving the computation that miners officially authorize the monetary transactions.

Miners utilize the best computers with a high hash rate computing power. Thus, the higher the number of calculations performed every second, the increased likelihood that the miner will receive the compensation for mining that block. Thus, block mining is a continuous cycle which is rapidly increasing daily as many organizations and individuals all over the world seek the opportunity for steady income via mining blockchain data. Digiconomist (2020) estimates a total of $12,764,204,701 USDs of possible mining income per year. Current miner profit ranges from $11.41 USD to -$3.36 USD per hour using a graphics processing unit (GPU) (WhatToMine, 2021). These calculations depend upon the hardware, geographic location, and consensus protocols.

Miner hardware may be a personal computer processing unit (CPU), a graphics processing unit (GPU), or an Application-Specific Integrated Circuit (ASIC). However, using CPUs for mining is not profitable today. Instead, the most common hardware used in mining is the GPU. The GPU is a high intensity gaming unit that is designed to be added to the motherboard or a personal computer or purchased with a gaming machine. Meanwhile, ASIC is a costly industrial machine that is the most powerful and efficient for mining. However, very few companies or individual miners use ASIC due to the cost (HIVE Blockchain Technologies Ltd., 2018).

Several websites analyze the mining trends and assist in computing profitability based on the miners' hardware. One website, whattomine.com, allows miners to compare various hardware, energy, and hashing output applied to a range of minable blockchains. Whattomine.com provides details on ASIC and GPU hardware. The website provides hashing rates, energy use, costs, and profitability. Websites, such as whattomine.com, support the question asked by miners, 'where should I mine?' (Spiegelman, et al., 2018). The website has also been used for calculating cryptocurrency revenue (Ivar and Pawar, 2018).

Currently, Stachowski, Fiebig, and Rauber (2020) researched frequency scaling towards energy efficient algorithms. They provide an optimal energy efficient framework for automatic improvement on NVIDIA graphics processing units (GPUs) of the mining process. Results show that various energy efficiencies exist with a variety of GPUs and currency mining that can double mining profit. Thus, their work enables a foundation for other researchers to build upon when exploring the mining process of blockchain.

Geographic location of the miner also plays a part in mining profit. For example, a vast majority of the first generation platforms or Bitcoin miners are geographically located in China and rely on coal-based energy (Stoll, Klaaßen, L., & Gallersdörfer, 2019). Enormous amounts of energy are consumed by the hardware during the mining process (Giungato, Rana, Tarabella, & Tricase, 2017; Gulli, 2020). BitcoinCashout (n.d.) stated that "it has been recorded that a single bitcoin mining uses almost as much as 35,518 kWh is consumed". Furthermore, Digiconomist's (2020) Bitcoin Energy Consumption Index reported that one Bitcoin transaction has the similar energy consumption as 100,000 visa transactions. Thus, energy consumption is extremely high, making it not so profitable for the first generation miners and causing environment concerns for the world. However, miners of second generation platforms are significantly more profitable and have less of a carbon footprint.

Second generation platforms tend to progress in throughput and scalability via a complete programable infrastructure via the employment of smart contracts. Most existing blockchain platforms that are not dealing with digital currency are second generation platforms. Second generation platforms utilize better consensus protocols including Proof of Stake (PoS) or Proof of Assignment (PoA). Therefore, the energy consumption and carbon emissions are significantly lower than the first generation platforms (Paulavicius et al., 2019). However, the energy consumption also has environmental concerns.

Purpose of this study

The goal of this research is to explore the current on innovative blockchain usage, structure, generations, and energy consumption through the literature. The research also provides an energy consumption comparison for consensus protocols and a list of recommendations for the implementation of a green blockchain.

Methodology

This study compared the energy consumption for three popular blockchains, Bitcoin, Ethereum, and Polkadot. Bitcoin was selected because it is the most widely known blockchain that utilizes PoW consensus. Ethereum is the second most widely known blockchain. Polkadot is the fifth most widely known blockchain and uses PoS consensus based on market capitalization (CoinMarketCap, 2021).

To express the energy consumption for Bitcoin and Ethereum, the Cambridge Bitcoin Electricity Consumption Index (CMECI) for assessing Bitcoin's electricity consumption was utilized. CMECI formula was used because it takes into account the network hash rate, miner revenues, mining equipment efficiency, electricity cost, and data center efficiency. CMECI also accounted for changes in mining equipment and profitability to offer a lower and upper boundary on energy consumption by utilizing a best guess estimate which provided a constant score of 1.01 for the lower boundary and 1.2 for the upper boundary (Cambridge Centre for Alternative Finance, 2021). Figure 1 illustrates the CMECI formula for energy consumption.

$$E_{lower}\left(P_{el}\right) = min\left(Eq_{prof}\left(P_{el}\right)\right) * H * PUE * 3.16 * 10^{7},$$

$$with$$

$$E_{lower} \; - \; lower\ bound\ power\ consumption\ [W]$$

$$min\left(Eq_{prof}\left(P_{el}\right)\right) \; - \; energy\ efficiency\ of\ the\ most\ efficient\ hardware\ [J/h]$$

$$H \; - \; hashrate\ [h/s]$$

$$PUE \; - \; power\ usage\ effectiveness$$

Figure 2. CMECI Expression for Energy Consumption (Cambridge Centre for Alternative Finance, 2021)

Utilizing information publicly available on the Internet, the current hash rate for both Bitcoin and Ethereum were queried directly from their respective blockchain. Bitcoin's global hash rate was retrieved by typing "getnetworkhashps" in a console window running Bitcoin. Specifically, this study utilized a public blockchain website (blockchain.com) to find Bitcoin's hash rate of 180 EH/s. The current block height at 669,612 had a difficulty of 21,434,395,961,389.92.

Ethereum's global hash rate was also found on public websites including etherescan.io. We found Ethereum's hash rate was 389,600 Gh/s with a difficulty of 4,850 TH/s and a transaction time of 12.4 seconds on the most recent block (etherescan.io).

Next, the energy consumption for Polkadot was found. However, because Polkadot employed PoS as its consensus, a different formula was used. Specifically, the following formula was implemented to compute Polkadot's energy consumption:

Polkadot Energy Consumption = Energy per server * number of servers * 24 hours * 365 days

PoS platforms utilized validators (servers) as the mechanism for consensus. The validators are selected based on the total amount of stake or collateral. Data retrieved from the public telemetry website (https://telemetry.polkadot.io/#/Polkadot) accessed on February 8, 2021 showed that Polkadot had 732 validators. However, Polkadot's specific type of server used for validation was not identified. Thus, the server may be virtual, standalone, or part of the data center. Since specific server information was unknown, a rack mounter server (Dell R730) was selected from Dell's catalog. Dell's catalog was selected because they provided a product carbon footprint analysis on all items (Dell, 2019). Dell's R730 server's energy consumption was listed at 168w/h.

Finally, after the energy comparison of consensus protocols, recommendations were made for implementing a greener blockchain. Using the Delphi approach, the researcher explored the literature above and created a list of recommendations. The four authors served as the panel of experts as each author has studied blockchain and has experience within the industry or published scholarly blockchain manuscripts. The authors interacted via e-mail to formulate the recommendation list until an agreement was reached. The results from each stage centered around a discussion regarding what recommendations can be implemented at the organizational level and miner level and what resources we can suggest for the reader the learn more information about our recommendations. The final consensus was reached after six passes.

Results

Energy Comparison of Consensus Protocols

As defined above, blockchain platforms tended to explore different consensus protocols. Each consensus protocol has different energy consumption. Results illustrate that Bitcoin and Ethereum (PoW consensus) consume significantly more energy than PolkDot (PoS consensus). Table 2 provides the exact energy consensus details for PoW and PoS platforms.

Table 2. Consensus Energy Consumption

Blockchain	Consensus Protocol	Energy Consumption Calculation
Bitcoin	PoW	3500 * 180,000,000/110 *1.01*3.16 *10^7= **1.**8TWh (lower) 2640 * 180,000,000/24 *1.2*3.16*10^7 = 7.5TWh (upper)
Ethereum	PoW	2500 * 389,600/2 *1.01*3.16*10^7 = 1.55 TWh (lower) 860 * 389,600/.5 * 1.2*3.16*10^7 = 2.54 TWh (upper)
Polkadot	PoS	168(wh) * 730 (Servers) * 24(h) * 365(d) = 1 GWh

Recommendations

While there are many alternatives such as encouraging research and development to reduce energy consumption; or proposing to outsource to blockchain technology to countries where energy is cheap, the author's believe that the framework for a greener blockchain needs to begin with legislation from countries employing miners and implementing blockchain. This will not be an easy task due to the uniqueness of blockchain. While waiting for legislation to be made, simple contentious steps can be taken to help provide a greener blockchain. Table 3 provides a list of recommendations to consider for implementing a green blockchain.

Table 3: Recommendations for Implementing a Green Blockchain

Recommendation	Recommendation of company/name to seek more information	URL for More information
Organizational Level		
Avoid using Proof of Work Consensus Platforms		
Consider building community blockchains	ComChain	https://www.redbellyblockchain.io or https://www.redbellyblockchain.io/researchpapers
Seek out companies providing 100% renewable energy	Northern Data	https://northerndata.de/
Miner Level		
Before mining check energy consumption of your device		https://www.saveonenergy.com/energy-resources/energy-consumption/
Before mining check profitability of mining within your geographic location	Coin Mining Stats	https://coinminingstats.com or https://www.whattomine.com/
Utilize GPUs that are new and noted as an Energy Star	Energy Star	https://www.energystar.gov/products/office_equipment/computers
Monitor your power consumption during the mining process	Simple Mining	https://simplemining.net/
Seek out renewable energy such as solar or wind energy	Cryptosolartech	https://www.cryptoglobe.com/latest/2018/10/bitcoin-miner-to-build-300mw-solar-farm-for-sustainable-crypto-mining/

Conclusion

As more organizations look to implement or embrace blockchain innovations, research must focus on making the blockchain greener. This research explored current innovative blockchain usage, structure, generations, and energy consumption. Furthermore, an energy consumption comparison for consensus protocols was provided along with a list of recommendations for implementing green blockchains. However, this research is limited as it is theoretical in nature because it did not test any of the information described. It is also limited in that it only assumes public blockchain energy consumption. It also assumes that all information is stored on the block and not off the block. Additional research should address these limitations.

Regardless of the limitations, this paper has practical implications for higher education faculty teaching blockchain as it adds to the existing body of literature on blockchain. This paper also has significant implications for practitioners needing an overview of current knowledge and recommendations to consider for green blockchain implementation.

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