Exploring Blockchain Technologies: Insights Into Consensus Mechanisms, Mining Pool Dynamics, and Energy Consumption Patterns

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***Abstract*— Blockchain technologies and cryptocurrencies have garnered significant attention for their potential to revolutionize various industries. This paper investigates the landscape of blockchain technologies in the context of cryptocurrencies, focusing on performance metrics, trade-offs, trends, and underlying issues. Through comprehensive analysis, the most utilized consensus mechanisms among the top cryptocurrencies are identified. The distribution of top mining pools by hash rate over the last two years reveals dominance by a few major pools, with implications for decentralization and security. In Bitcoin mining pool distribution, trends indicate the dominance of established pools like Foundry USA Pool and AntPool, alongside notable growth from smaller pools like MARA Pool and Luxor. Comparative analysis across different cryptocurrencies highlights variations in hashing rate, block production, and energy consumption, underscoring the complex dynamics of blockchain mining. Moreover, the comparative analysis of energy consumption in blockchain mining hardware reveals insights into energy efficiency and sustainability. Smaller mining pools demonstrate significant growth and momentum, contributing to the diversification and decentralization of mining operations.**

Keywords*— *blockchain, performance metrics, trade-offs. trends, mining pool, energy consumption

I. INTRODUCTION

Since its introduction by Nakamoto [1], blockchain technologies have been extensively studied in numerous domains [2], [3], [4] due to the notion that they possess the potential to provide alternative solutions to existing issues or applications, owing to their attributes of decentralization, transparency, autonomy, security, and immutability [5].

Blockchain serves as the foundational technology for many emerging applications that have gained traction recently. The blockchain network operates as a decentralized, distributed ledger system, requiring consensus among all nodes to validate shared ledgers. Consensus mechanisms are crucial for upholding the reliability and safety of blockchain networks, as they foster consensus among participants. By leveraging cryptographic methods, these mechanisms create trust and enable direct peer-to-peer transactions, eliminating the necessity for intermediaries [6].

Cryptocurrencies, as one and the first of the prominent applications of blockchain, have garnered significant attention for their role in reshaping financial transactions, asset management, and decentralized applications. Bitcoin, the pioneering and widely recognized digital currency, has opened doors for numerous other cryptocurrencies, each presenting distinctive attributes and capabilities. Ethereum, for example, revolutionized the landscape by introducing smart contracts, empowering developers to build decentralized applications (DApps) on its blockchain network [7]. This innovation has led to the proliferation of a diverse ecosystem of tokens and decentralized finance (DeFi) platforms, further expanding the potential applications of blockchain technology [6], [8].

II. METHODOLOGY

The methodology for investigating blockchain technologies involves a comprehensive approach to address various research questions. Firstly, an analysis of consensus mechanisms prevalent among top cryptocurrencies will be conducted, followed by an examination of mining pool distribution trends. Comparative analyses will then be performed to evaluate cryptocurrency metrics and energy consumption patterns across different blockchain networks and mining hardware models. Additionally, qualitative exploration will uncover growth strategies of smaller mining pools. Through this approach, a holistic understanding of blockchain technologies will be attained, covering consensus mechanisms, mining pool dynamics, cryptocurrency metrics, energy consumption, and growth strategies of mining pools.

A. Research Questions

Within the scope of the investigation, the research questions (RQ) are as follows: RQ1: What are the most used consensus mechanisms among the top cryptocurrencies, and how do they compare in terms of hashing rate, block production, and energy consumption? RQ2: What insights can be drawn from the distribution of the top mining pools by hash rate over the last two years? RQ3: What are the key findings from the comparative analysis of energy consumption in blockchain mining hardware, and what are the dominant trends in Bitcoin mining pool distribution?

B. Data Collection

In data collection process, we employed a multifaceted approach to gather pertinent information about blockchain technologies and cryptocurrency ecosystems. Besides

academic publications, our primary data sources included reputable blockchain explorers, mining pool tracking websites, mining device websites, and official project documentation.

III. Results

Digital cryptocurrencies represent digital assets at the core of the modern financial ecosystem. Coins typically refer to digital currencies that operate on their own blockchains and are used as a means of payment. Examples include Bitcoin and Ethereum. On the other hand, tokens are digital assets usually built on existing blockchain networks and serve various purposes. Tokens can represent ownership in a project, represent a specific service or product, or be used for voting, among other purposes. These concepts play a significant role in the digital asset market with the adoption of blockchain technology, contributing to financial innovation and the development of the digital economy [9].

A. Cryptocurrencies and Consensus Mechanisms

As of 30 April 2024 (Table I), market capitalization of cryptocurrencies has reached to $2.30 trillion [15]. Bitcoin (BTC), utilizing PoW, leads with a market capitalization of $1.20 trillion. More than half of the cryptocurrency market (52.2%) is dominated by Bitcoin. Ethereum (ETH) follows with PoS at $367.08 billion. And BNB (Binance Coin) adopts a PoSA mechanism and holds a market cap of $84.02 billion. When considering the top three cryptocurrencies, they collectively represent 74.8% of the market.

TABLE I. Top 20 Cryptocurrencies and Market Capitalization

#	Name	Code	Consensus Mechanism	Market Cap. (billion)
1	Bitcoin	BTC	PoW	$1,200
2	Ethereum	ETH	PoS	$367.08
3	BNB	BNB	PoSA	$84.02
4	Solana	SOL	PoS	$57.48
5	XRP	XRP	FBA	$27.49
6	Dogecoin	OGE	PoW	$19.33
7	Toncoin	TON	PoS	$18.11
8	Cardano	ADA	Ouroboros (PoS[a])	$15.97
9	Avalanche	AVAX	PoS[a]	$12.47
10	TRON	TRX	DPoS	$10.63
11	Polkadot	DOT	NPoS	$8.75
12	Bitcoin Cash	BCH	PoW	$8.33
13	Polygon	TIC	PoS[a]	$6.57
14	Litecoin	LTC	PoW	$5.83
15	Ethereum Classic	ETC	PoW	$3.74
16	NEAR Protocol	NEAR	Nightshade	$3.71
17	Hedera	HBAR	Gossip protocol	$3.36
18	Filecoin	FIL	EC (BFT[a])	$3.05
19	VeChain	VET	PoA	$2.62
20	Cosmos	TOM	Tendermint BFT	$2.56

[a]. Modified

Consensus mechanisms, in conjunction with cryptographic methods, create trust and enable direct peer-to-peer transactions, eliminating the necessity for intermediaries [6], [10]. Upon examining the consensus mechanisms of the top 20 coins with the highest market share, it is evident that Proof of Work (PoW), Proof of Stake (PoS), and Byzantine Fault Tolerance (BFT) are prominent (Table I). is a PoW consensus mechanism widely utilized in blockchain networks, including Bitcoin and Ethereum. In PoW, miners compete to solve complex mathematical puzzles to verify transactions and create new blocks on the blockchain. The miner who solves the puzzle first gets to add the next block and is rewarded with cryptocurrency. While PoW is secure and proven effective, it requires substantial computational power and energy consumption [11], [12]. PoS is an alternative consensus mechanism where validators are chosen to create new blocks based on the amount of cryptocurrency they hold and are willing to "stake" as collateral. In PoS, there are no miners competing to solve puzzles; instead, validators are selected deterministically, typically based on factors like their stake and the length of time they've held their coins. PoS is considered more environmentally friendly and more resource-efficient compared to PoW but has its own set of challenges, including the "nothing-at-stake" problem [11], [12]. Proof of Stake Authority (PoSA) [13] is a variation of PoS that incorporates trusted authorities to select validators, enhancing security and scalability. In PoSA, a predefined set of authorities are responsible for choosing validators, which can lead to faster block confirmations and reduced energy consumption compared to traditional PoW systems. Delegated Proof of Stake (DPoS) [14] is a consensus mechanism where token holders vote for a select number of delegates to verify transactions and produce blocks on their behalf. These delegates are responsible for securing the network and ensuring consensus. DPoS aims to combine the benefits of decentralization with efficient block production, as token holders can vote for delegates who represent their interests in the network's governance.

B. Mining Pools

Mining pool is a collective network of miners who collaborate by pooling their resources to solve blocks. This allows miners to solve blocks more quickly and distribute block rewards more fairly. Due to Bitcoin's dominance in the market, it has the potential to serve as a significant indicator in terms of mining. In this study, Bitcoin mining is examined as an example while analyzing mining pools. The findings of the analysis reveal that Bitcoin mining pool hash rate distribution [15] from 2022 to 2024, reveals significant fluctuations among major pools. The distribution of mining pools for Bitcoin is as follows: Foundry USA Pool leads with 29.15%, followed by AntPool at 22.09%, and ViaBTC at 12.35%. F2Pool holds 10.98%, while Binance, MARA Pool, Luxor, Braiins Pool, and Spider Pool follow with 4.16%, 3.75%, 3.06%, 2.91%, and 2.79%, respectively. BTC.com closes the list with 1.95%. Interestingly, smaller pools such as MARA Pool and Luxor displayed noticeable growth, albeit from a smaller base, while newcomers like Spider Pool gained momentum, reaching 2.79% by April 26, 2024 (Table II).

Figure 1 depicts the distribution of top 10 mining pools by hash rate over the last two years. Throughout this period, there have been fluctuations; however, the top ten mining

pools have consistently maintained control over more than 90% of the total hash rate (Fig. 2).

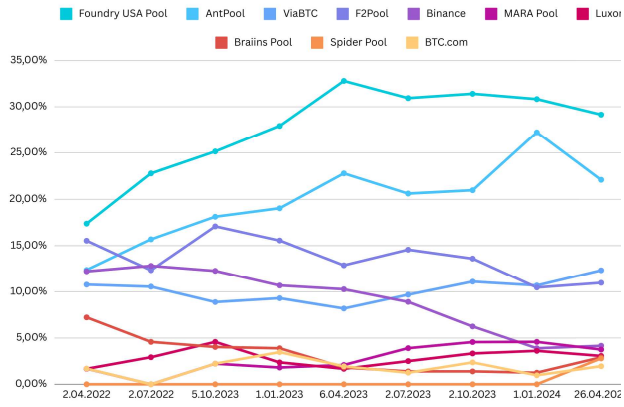

Fig. 1. Distribution of top 10 mining pools by hashrate over the last two years.

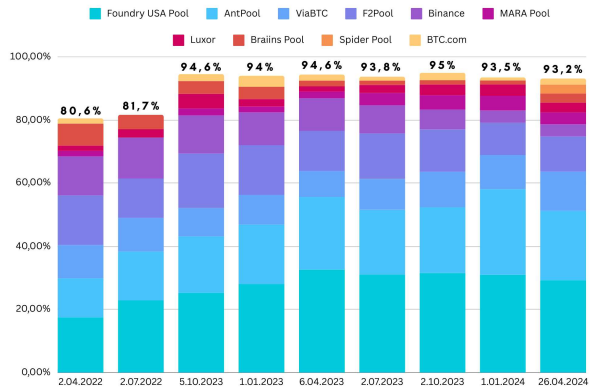

Fig. 2. Cumulative distribution of top 10 mining pools by hashrate over the last two years.

Table III presents the contributions of various mining pools to the Bitcoin network during the period spanning from April 23 to April 26, 2024. The top three pools by contribution are Foundry USA, AntPool, and ViaBTC, collectively accounting for the majority of the network's mining power. Foundry USA leads with a contribution of 28.29%, followed closely by AntPool at 24.34%, and ViaBTC at 11.68%.

Mining pools have developed various systems for reward distribution purposes. Among these, prominent ones include Pay-Per-Share (PPS), Full Pay-Per-Share (FPPS), Pay-Per-Share Plus (PPS+), and Pay-Per-Last-N-Shares (PPLNS). PPS a payment model where miners receive a fixed reward for each valid share they contribute to the pool's mining effort, regardless of whether the pool successfully mines a block or not. In FPPS system, miners receive a fixed reward based on the hash power they contribute to solving blocks. When a block is confirmed, the block reward is distributed fairly among miners, with each miner receiving a fixed share independent of transaction fees. In PPS+, miners are paid a fixed payment for their efforts in solving blocks. Miners receive a fixed block reward when they confirm a block, but transaction fees are collected by the pool and later distributed to miners. This ensures miners have a steady income, while allowing the pool to retain the potential for revenue from transaction fees. In PPLNS, miners are rewarded based on the number of shares they contributed to the pool's mining efforts over a certain period, typically the last N shares. The reward is distributed proportionally among miners based on their share of the total shares contributed during that period [16].

TABLE III. BITCOIN MINING POOLS - REWARD SYSTEM & CONTRIBUTION

#	Mining Pool	Reward System	Country	Contribution
1	Foundry USA	FPPS	USA	28,29%
2	AntPool	FPPS	CN	24,34%
3	ViaBTC	PPS+	CN	11,68%
4	F2Pool	PPS+	CN	10,86%
5	Unknown	-	-	8,39%
6	Binance Pool	FPPS	CN	4,28%
7	Mara Pool	PPLNS	USA	3,95%
8	Braiins Pool[a]	FPPS	CZ	2,14%
9	BTC.com	FPPS	CN	1,98%
10	SBI Crypto[b]	FPPS	JP	1,81%

a. SlushPool (November 2010) named after Braiins Pool

b. Became public at April 2021

When considering the distribution of Bitcoin mining pools between April 23rd and April 26th, 2024, it is evident that two systems stand out prominently. These systems are known as FPPS and PPS+ systems. Foundry USA, AntPool, Binance Pool, BTC.com, and SBI Crypto employ the FPPS system, while ViaBTC and F2Pool opt for the PPS+ system. Additionally, Mara Pool utilizes the PPLNS system. This variety in reward systems reflects the diverse strategies employed by mining pools to incentivize miners and distribute rewards efficiently (Table III).

Regarding the geographical distribution, the majority of the top mining pools are based in Republic of China (CN),

TABLE II. TOP 10 BITCOIN MINING POOL MARKET SHARE ANALYSIS (2022-2024)

Pool Name	2.04.2022	2.07.2022	5.10.2023	1.01.2023	6.04.2023	2.07.2023	2.10.2023	1.01.2024	26.04.2024
Foundry USA Pool	17,38%	22,78%	25,14%	27,92%	32,80%	30,94%	31,41%	30,83%	29,15%
AntPool	12,39%	15,69%	18,12%	19,03%	22,78%	20,61%	20,97%	27,22%	22,09%
ViaBTC	10,78%	10,56%	8,89%	9,31%	8,19%	9,69%	11,11%	10,69%	12,35%
F2Pool	15,54%	12,36%	17,08%	15,56%	12,89%	14,57%	13,61%	10,47%	10,98%
Binance	12,24%	12,83%	12,29%	10,69%	10,28%	8,91%	6,25%	3,89%	4,16%
MARA Pool	1,68%	0,00%	2,22%	1,81%	2,08%	3,90%	4,56%	4,58%	3,75%
Luxor	1,67%	2,92%	4,58%	2,36%	1,67%	2,50%	3,33%	3,61%	3,06%
Braiins Pool	7,23%	4,58%	4,03%	3,89%	1,81%	1,39%	1,39%	1,25%	2,91%
Spider Pool	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	2,79%
BTC.com	1,69%	0,00%	2,22%	3,47%	1,94%	1,25%	2,36%	0,97%	1,95%
	80,60%	**81,72%**	**94,57%**	**94,04%**	**94,44%**	**93,76%**	**94,99%**	**93,51%**	**93,19%**

with AntPool, ViaBTC, F2Pool, Binance Pool, and BTC.com representing notable contributions from the country. Foundry USA and Mara Pool contribute significantly from the United States (USA), while Braiins Pool operates from Czechia (CZ), and SBI Crypto represents Japan (JP). It should be noted that this distribution provides information regarding the headquarters of the companies. Indeed, these companies have servers and conduct operations across multiple continents and countries [17].

C. Application-Specific Mining Devices

Cryptocurrency mining has evolved significantly over the years, driven by advancements in hardware technology and the increasing complexity of cryptographic algorithms. One notable innovation in this domain is the Application-Specific Integrated Circuit (ASIC) device, engineered specifically for the purpose of mining cryptocurrencies. These specialized hardware components have revolutionized the mining landscape by offering unparalleled efficiency and performance compared to traditional computing hardware. In this context, the ASIC device stands out as a key enabler of efficient mining operations, characterized by its ability to execute hashing algorithms with remarkable speed and energy efficiency [18].

In this study, we will conduct calculations based on Bitcoin as it dominates market share. Table IV includes various ASIC devices produced for Bitcoin mining, each with different power consumption and processing capacities.

D. Power Consumption

In the context of blockchain mining, power consumption plays a significant role in understanding the energy dynamics of the process. The number of devices (1) utilized to mine a block within a specified timeframe is calculated using the formula [21]:

$$ND - ceil\left(\frac{Hash\ rate\ (Th/s)}{Device\ hash\ rate\ (Th/s)}\right) \quad (1)$$

$$ceil(x) = min\{n \in Z : n \geq x\} \quad (2)$$

Here, the hash rate represents the overall network hash rate, while the device hash rate denotes the hashing power of an individual mining device. The function (x) denotes the ceiling function (2), which rounds up the value of x to the nearest integer. This calculation enables us to determine the minimum number of devices required to achieve the desired hash rate within the given timeframe.

TABLE IV. COMPARISON OF ASIC DEVICES FOR BITCOIN MINING

#	ASIC Name	Release Date	Algo.	Watts	TH/s
1	Antminer S21 Pro	Mar 29, 2024	SHA256	3,510	234
2	Whatsminer M63S Hydro	Oct 25, 2023	SHA256	7,215	390
3	Whatsminer M63 Hydro	Oct 25, 2023	SHA256	6,646	334
4	Avalonminer A1446	Sep 1, 2023	SHA256	3,310	135
5	Antminer S19 pro	May 1, 2020	SHA256	3,250	110
6	Innosilicon Turbo hf+	Jul 1, 2020	SHA256	2,600	33
7	Bitfury B8	Dec 1, 2017	SHA256	6,400	64
8	Gmo B2	Oct 1, 2018	SHA256	1,950	24
9	Antminer S9	Nov 1, 2017	SHA256	1,372	14
10	Ebit E9.2	May 1, 2018	SHA256	1,320	12

Furthermore, the power consumption for block mining (denoted as Wc) is computed for each blockchain network using the expression:

$$Wc(KWh) = P(KW) \times TAv(h) \times ND \quad (3)$$

In this equation (3), $P(KW)$ represents the power consumption of the mining operation in kilowatts, $TAv(h)$ denotes the average time taken to mine a block in hours, and ND signifies the number of devices utilized for mining. By multiplying these factors, we can estimate the total energy consumed (in kilowatt-hours) during the process of block mining for a given blockchain network.

Table V presents a comparison of hashing rates and mining statistics across various cryptocurrencies during the period from April 22 to April 28, 2024. Bitcoin emerges as the dominant cryptocurrency with a hashing rate of 6.44 x 10^8 TH/s, mining an average of 146.5 blocks per day with an average mining time of 9.83 minutes per block. Bitcoin Cash follows with a hashing rate of 4.35 x 10^6 TH/s, mining 147.5 blocks per day with an average mining time of 9.76 minutes per block. Bitcoin SV exhibits a hashing rate of 6.68 x 10^5 TH/s, mining 143.2 blocks per day with an average mining time of 10.06 minutes per block. Other cryptocurrencies such as Dash, Dogecoin, Litecoin, Ethereum Classic, Zcash, Monero, Vertcoin, and Bitcoin Gold also demonstrate varying hashing rates and mining statistics, reflecting the diverse landscape of cryptocurrency mining activities.

Table VI presents an insightful comparison of the approximate kilowatt-hour (Kwh) consumption for generating a single block across various blockchain ASIC devices. These devices include the Whatsminer M63S Hydro, Whatsminer M63 Hydro, Antminer S21 Pro, Avalonminer A1446, Antminer S19 Pro, Bitfury B8, Innosilicon Turbo HF+, Gmo B2, Antminer S9, and Ebit E9.2.

Analyzing the data reveals notable variations in energy consumption across different cryptocurrencies and mining hardware. For instance, in Bitcoin mining, the Bitfury B8 and Antminer S9 demonstrate relatively lower energy consumption compared to other devices. Conversely, in Bitcoin Cash and Bitcoin SV mining, the Antminer S19 Pro and Bitfury B8 exhibit competitive energy efficiency.

Dash mining showcases similar trends, with the Antminer S19 Pro and Bitfury B8 consuming relatively less energy per block generation. Dogecoin, Litecoin, and Vertcoin mining also witness comparable energy consumption patterns among the analyzed devices.

TABLE V. COMPARISON OF HASHING RATES AND MINING STATISTICS

#	Name	Hash rate (TH/s)	Avg. blocks/day	Avg. mining time/block (m)
1	Bitcoin	6,44E+08	146.5	9,83
2	Bitcoin Cash	4,35E+06	147.5	9,76
3	Bitcoin SV	6,68E+05	143.2	10,06
4	Dash	2,32E+03	547.7	2,63
5	Dogecoin	1,08E+03	1,349.6	1,07
6	Litecoin	1,05E+03	582.3	2,47
7	Ethereum Classic	1,75E+02	6,457.4	0,22
8	Zcash	8,00E-03	1,144.7	1,26
9	Monero	2,00E-03	722.2	1,99
10	Vertcoin	1,00E-03	584.7	2,46

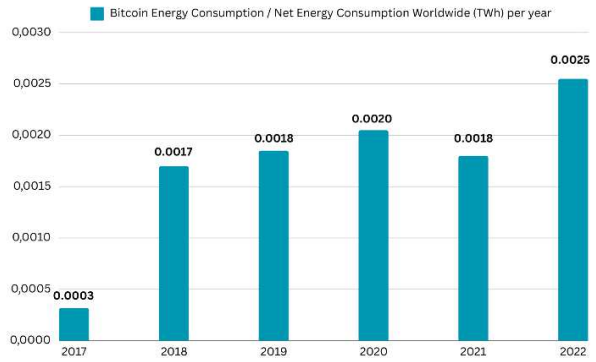

Fig. 3. Ratio of the electricity consumption of Bitcoin to the net global electricity (TWh)

However, Ethereum Classic, Zcash, Monero, and Bitcoin Gold mining highlight variations in energy efficiency across different hardware models. The Bitfury B8 consistently demonstrates lower energy consumption across these cryptocurrencies compared to other devices. When examining the ratio of the minimal electricity consumption of Bitcoin to the net global electricity consumption [19], this ratio increased by 41% compared to the previous year, reaching 0.25% in 2022 (Fig. 3). The minimal electricity consumption of Bitcoin rose by around 65% in 2023, whereas its increase was 42.4% in 2022 (Fig. 4).

IV. Discussion

Cryptocurrencies, the prominent application of blockchain, have reshaped financial transactions and decentralized applications. Bitcoin, the pioneer cryptocurrency, has paved the way for numerous digital assets, each introducing unique features. Ethereum, with its introduction of smart contracts, has fostered the development of decentralized applications and a thriving ecosystem of tokens and DeFi platforms.

In this study, we explored the intricate dynamics of blockchain technologies, focusing on performance metrics, trade-offs, trends, and underlying issues. Through comprehensive analysis, we illuminated the current landscape and future prospects of blockchain and cryptocurrencies. Additionally, we delved into the energy consumption of mining hardware, contributing to the discourse on sustainability and efficiency in blockchain operations.

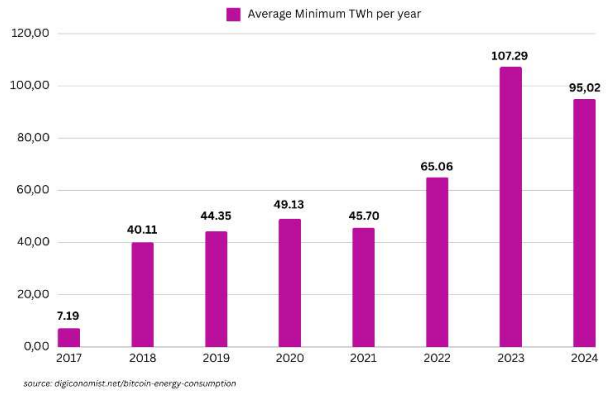

Fig. 4. Average minimum energy consumption of Bitcoin (TWh)

RQ 1: What are the most used consensus mechanisms among the top cryptocurrencies, and how do they compare in terms of hashing rate, block production, and energy consumption?

The analysis reveals that PoW, PoS, and variations like PoSA and DPoS are the most utilized consensus mechanisms among the top cryptocurrencies. Bitcoin and Ethereum, the leading cryptocurrencies by market capitalization, employ PoW and PoS, respectively. PoW, known for its security and effectiveness, requires significant computational power and energy consumption, while PoS offers a more energy-efficient alternative. PoSA and DPoS introduce trusted authorities or elected delegates to enhance security and scalability. The comparative analysis of hashing rate, block production, and energy consumption reveals varying performance metrics and trends. Bitcoin, as the market leader, has the highest hashing rate and block production. Other cryptocurrencies such as Bitcoin Cash, Bitcoin SV, Dash, and Dogecoin also show significant hashing rates and block production, albeit at varying levels. Energy consumption varies across cryptocurrencies and mining hardware models, impacting environmental sustainability and resource efficiency.

RQ2: What insights can be drawn from the distribution of the top mining pools by hash rate over the last two years?

The examination of top mining pool distribution by hash rate over the last two years reveals significant fluctuations and dominance by a few major pools. Despite these fluctuations, the top ten mining pools consistently maintain control over more than 90% of the total hash rate. Foundry USA Pool, AntPool, and ViaBTC emerge as the leading contributors, reflecting the concentration of mining power within a few entities. These findings underscore potential implications for decentralization and security in blockchain networks, as a few dominant pools wield significant influence over network operations.

RQ3: What are the key findings from the comparative analysis of energy consumption in blockchain mining hardware, and what are the dominant trends in Bitcoin mining pool distribution?

In the context of Bitcoin mining pool distribution, certain trends emerge from the analysis. Foundry USA Pool, AntPool, and ViaBTC dominate the landscape, collectively contributing a substantial portion of the network's mining power. However, smaller pools such as MARA Pool and Luxor display notable growth, indicating a dynamic and evolving ecosystem. Newcomers like Spider Pool also gain momentum, highlighting the potential for emerging players to challenge the dominance of established pools. These trends underscore the dynamic nature of Bitcoin mining pool distribution, with implications for network decentralization and resilience.

The comparative analysis of energy consumption in blockchain mining hardware yields several key findings. Different cryptocurrencies and mining hardware exhibit varying energy efficiency, with certain devices consuming less energy per block generation compared to others. Bitfury B8 consistently demonstrates lower energy consumption across multiple cryptocurrencies, highlighting its efficiency and potential for sustainable mining practices.

TABLE VI. COMPARATIVE ANALYSIS OF ENERGY CONSUMPTION IN BLOCKCHAIN MINING

Name	Whatsminer M63S Hydro	Whatsminer M63 Hydro	Antminer S21 Pro	Avalonminer A1446	Antminer S19 pro	Bitfury B8	Innosilicon Turbo hf+	Gmo B2	Antminer S9	Ebit E9.2
Bitcoin	1,95E+06	2,10E+06	1,58E+06	2,59E+06	3,12E+06	1,05E+00	4,26E-01	3,19E-01	1,58E-01	1,77E-01
Bitcoin Cash	1,94E+06	2,08E+06	1,57E+06	2,57E+06	3,10E+06	1,04E+00	4,23E-01	3,17E-01	1,57E-01	1,76E-01
Bitcoin SV	2,00E+06	2,15E+06	1,62E+06	2,65E+06	3,19E+06	1,07E+00	4,36E-01	3,27E-01	1,61E-01	1,81E-01
Dash	5,22E+05	5,61E+05	4,23E+05	6,92E+05	8,34E+05	2,80E-01	1,14E-01	8,54E-02	4,22E-02	4,74E-02
Dogecoin	2,12E+05	2,28E+05	1,72E+05	2,81E+05	3,38E+05	1,14E-01	4,62E-02	3,47E-02	1,71E-02	1,92E-02
Litecoin	4,91E+05	5,28E+05	3,98E+05	6,51E+05	7,84E+05	2,64E-01	1,07E-01	8,04E-02	3,97E-02	4,46E-02
Ethereum Classic	4,43E+04	4,76E+04	3,59E+04	5,87E+04	7,07E+04	2,38E-02	9,66E-03	7,25E-03	3,58E-03	4,02E-03
Zcash	2,50E+05	2,69E+05	2,03E+05	3,31E+05	3,99E+05	1,34E-01	5,45E-02	4,09E-02	2,02E-02	2,27E-02
Monero	3,96E+05	4,26E+05	3,21E+05	5,25E+05	6,32E+05	2,13E-01	8,64E-02	6,48E-02	3,20E-02	3,59E-02
Vertcoin	4,89E+05	5,26E+05	3,97E+05	6,48E+05	7,81E+05	2,63E-01	1,07E-01	8,00E-02	3,95E-02	4,44E-02
Bitcoin Gold	1,95E+06	2,10E+06	1,58E+06	2,59E+06	3,12E+06	1,05E+00	4,26E-01	3,19E-01	1,58E-01	1,77E-01

However, variations in energy consumption across different hardware models underscore the complex interplay between technology, resource efficiency, and environmental impact in blockchain mining. Smaller mining pools demonstrate notable growth and momentum in recent years, as evidenced by the analysis. MARA Pool, Luxor, and newcomers like Spider Pool exhibit significant growth rates, albeit from a smaller base. This trend highlights the dynamic and competitive nature of the mining ecosystem, with opportunities for emerging pools to challenge the dominance of established players. The growth of smaller pools underscores the potential for diversification and decentralization in mining operations, contributing to a more resilient and robust blockchain network architecture.

V. CONCLUSIONS & FUTURE WORKS

This study provides insights into blockchain technologies and cryptocurrencies. It analyzes consensus mechanisms, mining pool distribution, and comparative metrics across cryptocurrencies, highlighting the dominance of PoW and PoS mechanisms for security and energy efficiency in blockchain networks. Despite major pools concentrating mining power, smaller pools show growth, indicating diversification opportunities. Comparative energy consumption analysis underscores the need for sustainable blockchain mining practices. The findings suggest significant implications for green computing. High energy consumption by mining hardware and PoW underscores the need for energy-efficient solutions. Ethereum's transition to PoS suggests reducing blockchain's environmental impact. Efficient mining hardware like Bitfury B8 stresses selecting energy-efficient technologies. Adopting green computing practices can sustainably manage digital finance.

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