Cryptocurrency Mining: Finding Efficiency Through Hardware and Algorithm Tweaks

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Benjamin William Grant

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Technical Project Team Members

Benjamin Grant

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Briana Morrison, Department of Computer Science

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Benjamin Grant
Computer Science
The University of Virginia
School of Engineering and Applied Science
Charlottesville, Virginia USA
bwg9sbe@virginia.edu

ABSTRACT
An Ethereum mining computer I built as a personal project in 2021 had inefficiencies that wasted electricity and prevented it from mining as many coins as its hardware's potential would permit. Having taken courses at UVA that relate to this topic such as Algorithms, my solution was to examine the mining algorithm's code to find any inefficiencies. I spent many hours researching mining hardware as well as Ethash: the algorithm that the machine uses to mine Ethereum. This research yielded solutions to the hardware issues and many small tweaks in the mining algorithm's parameters that led to a 23% increase in hashrate (mining speed) and a 39% decrease in energy use. Given the hardware I chose, the computer is now able to mine at close to its full efficiency. Although, the setup will need additional tweaks in the future as algorithms change, cryptocurrencies change, and the whole field of cryptocurrency rapidly advances.

1. INTRODUCTION

Cryptocurrency mining, despite the notion that it is "niche" or uncommon to do, expends an incredible amount of energy. In a fact-sheet report by the White House, they stated that the energy usage of cryptocurrencies are "between 120 and 240 billion kilowatt-hours per year, a range that exceeds the total annual electricity usage of many individual countries, such as Argentina or Australia" [1]. Cryptocurrency mining accounts for an estimated 0.4% - 0.9% of total global energy usage (~127 TWh). Similarly, the carbon footprint of mining is at that same scale.

For technologies that are used by a vast majority of people (such as the internet), high energy expenditure would be less of an issue, but it is estimated that only 4.3% of the world's population is using cryptocurrency [2]. As more people become familiar with and use cryptocurrencies, the energy usage of miners will rise to meet increased demands. Thus, there are two main incentives for miners to make these computers as efficient as possible: to reduce negative environmental impacts and increase their own profits by paying less in electricity.

2. BACKGROUND

Before exploring the techniques and tools I used to improve my mining computer, it is important to understand the basics of cryptocurrency and mining. In simple terms, cryptocurrency is a digital currency that uses cryptography for security. It operates independently of a central bank and is decentralized, meaning it is not regulated by any government or financial institution [4]. It is akin to paying in cash, where you give a bill directly to another person (peer to peer).

Since the currency cannot be issued by some institution, where do the coins come from in the first place? The answer is mining. Mining is the process by which new cryptocurrency is created and transactions are verified. This process involves solving complex mathematical problems using computer hardware, and the first person or group to solve the problem is rewarded with a certain amount of cryptocurrency [4]. The term for this is called Proof of Work (PoW). Anyone with a computer is able to attempt these problems for a reward.

Typically, the hardware used for mining is a custom computer that uses high-end graphics processing units (GPUs) or application specific integrated circuits (ASICs). Tailoring the computer for the cryptocurrency you plan to mine is crucial for efficiency and profitability.

It is important to note that Ethereum, the cryptocurrency I mined using my machine in 2021, has since moved to a new algorithm that cannot be mined. This change called "The Merge" occurred in September 2022 [5]. I mined Ethereum from July 2021 until The Merge.

3. RELATED WORK

In order to address the high energy cost of running cryptocurrencies, many coins in recent years have been created with or "transferred" to a newer type of algorithm called Proof of Stake (PoS). A paper released by King and Nadal (2012) proposed a solution to the high energy usage of PoW (mineable) cryptocurrencies such as Bitcoin and Litecoin at the time. Instead of mining, their new method involved owners of a cryptocurrency "staking" their coins by temporarily giving them to the network to verify transactions for a reward. They stated that their algorithm would have the same security, thus "providing an energy efficient and more cost-competitive peer-to-peer crypto-currency" [3]. In fact, the energy usage of a cryptocurrency using PoS is negligible compared to its PoW counterpart. Ethereum, which switched to PoS in 2022, reduced its energy usage from 78 TWh to 0.0026 TWh annually (a 99.988% decrease) [6].

Since their paper in 2012, over 80 different cryptocurrencies have adopted a Proof of Stake mechanism. The top five as of April 2023 are listed below [12]:

	#	Name	Price	1h %
☆	2	Ethereum ETH	$1,980.85	▲0.06%
☆	7	Cardano ADA	$0.4176	▼0.22%
☆	10	Solana SOL	$23.00	▼0.52%
☆	26	Toncoin TON	$2.27	▼0.00%
☆	40	Algorand ALGO	$0.203	▼0.03%

Figure 1: Top Five PoS Cryptocurrencies

Although, to this day, there are debates on the security of PoS and concerns regarding the novelty of the protocol [11].

Touted by many as the most influential piece of literature surrounding cryptocurrency is the Bitcoin Whitepaper by Nakamoto (2008). This paper was the first to introduce a decentralized currency that solved the "double spend" issue where previous attempts had failed. Nakamoto's solution involved mining: people globally securing the Bitcoin network with their computer's processing power [4].

While I did not mine Bitcoin in 2021, Ethereum (pre-Proof of Stake) had a mining algorithm almost identical in structure to Nakamoto's design outlined in the Bitcoin Whitepaper.

4. COMPUTER DESIGN

Through my research I found that there were two ways to make a mining machine more efficient. First, by tweaking the hardware, meaning the physical components (cables / GPUs / processors), it is possible to reduce the energy usage. This is especially true for overpowered parts of the computer that are not used in the mining process. Second, the algorithm itself can be optimized for the specific hardware purchased for the machine.

4.1 COMPUTER COMPONENTS

The hardware I picked for this computer was eight Nvidia 3080 GPU's, an Intel Core i3-9100, 4Gb RAM, and a typical open mining case that allows for airflow. Other parts were used but are of little importance.

Figure 2: The Computer

4.2 HARDWARE OPTIMIZATION

My first theory was that I did not need as powerful a central processing unit (CPU) for my mining computer. As stated before, the graphics processing units (GPUs) are the only components running the mining algorithm, so having a powerful CPU is not necessary. The original CPU I purchased for my mining computer was the Intel Core i3-9100. This CPU has four cores each with a base frequency of 3.60GHz and a turbo frequency of 4.20GHz [7]. This meant the effective frequency at full speed was 16.8GHz. Inspecting the frequency of the CPU while mining, I found that only 3-4GHz were needed. Normally this is not an issue since the processor downregulates the speed when not needed, but there were many times that the CPU would unnecessarily jump to its max speed and use 50 watts of power. The processor I decided to purchase as a replacement was a Pentium Gold G-5400. Comparatively it was a much slower processor, with two cores at a maximum speed of 3.7GHz each (7.4GHz effective) [8].

I had another theory that the fans were not strong enough. A GPU has dynamic frequency scaling, essentially meaning that it slows itself down when its temperature exceeds a certain threshold [9]. To counter this I placed a large fan behind the machine that can be seen in the back of Figure 2.

4.3 SOFTWARE OPTIMIZATION

For the software, there were many different options that I experimented with to find the best fit for my specific setup. The first choice is what operating system to choose. I tested both Windows 10 and HiveOS: an operating system designed specifically for cryptocurrency mining. I also had to choose which mining application (think program on a computer) to use. NBminer, Gminer, Phoenix, Excavator and Trex were all options. I tested the last two since they were generally considered the most reliable at the time.

I also experimented with changing the parameters of the GPU's firmware.

Specifically, I turned down the core clock speed and increased the memory clock speed. Since a large portion of the RAM of the GPU is used to mine [10], I tested whether increasing memory speed in lieu of clock speed would be a beneficial tradeoff. The exact changes to each of those parameters is shown in the results below.

5. RESULTS

Note: Computation speed is measured in megahashes per second (MH/s), and power draw is in watts (W).

Change	Result
New CPU	-25W
Added large fan	+8% MH/s
HiveOS operating system	+2% MH/s vs Windows
Trex mining software	+3% MH/s vs Excavator
Reduced core clock -200 MHz	-10W but -2% MH/s
Increased memory clock +500 MHz	+12% MH/s but +20W
GPU power limit set to 230-240W	29% W decrease (each GPU -130W)
GPU full fan speed	+4% MH/s but +10W

Figure 3: Results of Changes on Hashrate and Wattage

Overall, by testing these different configurations of hardware and parameters within the software and GPU firmware, there was a ~39% reduction in energy usage and ~23% increase in hashrate. I calculated total percentages by comparing the computer's total power draw (W) and computation speed (MH/s) before and after these changes (rather than summing the individual results).

6. CONCLUSION

Considering the amount of energy cryptocurrency mining uses globally [1], it is important to make miners aware and prove that it is actually more profitable to focus on reducing energy expenditure.

While many miners are familiar with the idea of tweaking these "hidden" and hard-to-find parameters, those that do not will have machines that use 20-40% more electricity than needed. On top of this, there is little information detailing the effects of each specific change on the performance of the system. My hope is that this report will give insight into which of these changes are most important for mining computers in general.

7. FUTURE WORK

In the future, I may wish to update my results as I discover more tweaks and fine tune these findings for current algorithms. Future work could also include creating a guide that explains how to make each of these changes, allowing miners to achieve similar results without as much research.

REFERENCES

[1] 2022. FACT SHEET: Climate and Energy Implications of Crypto-Assets in the United States | OSTP. The White House. Retrieved April 21, 2023 from https://www.whitehouse.gov/ostp/news-updates/2022/09/08/fact-sheet-climate-and-energy-implications-of-crypto-assets-in-the-united-states/

[2] Global Cryptocurrency Ownership Data 2023. TripleA. Retrieved April 21, 2023 from https://triple-a.io/crypto-ownership-data/

[3] King, S., & Nadal, S. (2012). PPCoin: Peer-to-Peer Crypto-Currency with Proof-of-Stake. In Proceedings of the 2012 IEEE Symposium on Security and Privacy (SP) (pp. 456-470). ACM.

[4] Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system. Retrieved from https://bitcoin.org/bitcoin.pdf

[5] The Merge. Ethereum. Retrieved April 21, 2023 from https://ethereum.org/en/roadmap/merge/

[6] Ethereum Energy Consumption. Ethereum. Retrieved April 21, 2023 from https://ethereum.org/en/energy-consumption/

[7] Intel® CoreTM i3-9100 Processor (6M Cache, up to 4.20 GHz) Product Specifications. Retrieved April 21, 2023 from https://www.intel.com/content/www/us/en/products/sku/134870/intel-core-i39100-processor-6m-cache-up-to-4-20-ghz.html

[8] Intel® Pentium® Gold G5400 Processor (4M Cache, 3.70 GHz) - Product Specifications. Intel. Retrieved April 21, 2023 from https://www.intel.com/content/www/us/en/products/sku/129951/intel-pentium-gold-g5400-processor-4m-cache-3-70-ghz/specifications.html

[9] Dynamic Voltage and Frequency Scaling (DVFS). Semiconductor Engineering. Retrieved April 21, 2023 from https://semiengineering.com/knowledge_centers/low-power/techniques/dynamic-voltage-and-frequency-scaling/

[10] Gabriel Ayala. What is the Ethash mining algorithm? Retrieved April 21, 2023 from https://academy.bit2me.com/en/what-is-the-algorithm-of-ethash-mining/

[11] Akash Takyar. 2019. Proof of Work vs Proof of Stake : An In-Depth Discussion. LeewayHertz - Software Development Company. Retrieved April 21, 2023 from https://www.leewayhertz.com/proof-of-work-vs-proof-of-stake/

[12] Top PoS Tokens by Market Capitalization. CoinMarketCap. Retrieved April 21, 2023 from https://coinmarketcap.com/view/pos/