INDEPENDENT RESEARCH: INCREASING EFFICIENCY OF BITCOIN MINING HARDWARE

(Technical Report)

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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

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Abstract

This technical report presents a method developed to counteract planned obsolescence in Bitcoin mining hardware, specifically targeting ASIC miners like those from Bitmain, which are programmed to become less profitable over time. The author's software optimizes the operational parameters such as voltage and frequency, enabling miners to not only manage multiple units efficiently but also prolong the equipment's viable life span. Experimental results show that the optimized settings can lead to significant reductions in power consumption and enhanced profitability, achieving up to an 18% increase in mining efficiency. The research highlights the potential for extended hardware utility, reduction in e-waste, and environmental benefits, proposing future work to enhance software compatibility and user interface for broader application.

1. Introduction

In the early days of cryptocurrency mining, individuals could use their home computers to mine effectively. However, the development of Application-Specific Integrated Circuit (ASIC) miners has significantly transformed the industry. These ASIC miners require industrial-grade, power-intensive hardware, marking a shift from the accessibility of earlier methods. Companies such as Bitmain, a leading ASIC miner manufacturer, are driven by economic incentives to design their products with planned obsolescence. This strategy ensures a continuous demand for new hardware as older models become less efficient over time.

Specifically, Bitmain achieves this by embedding software within the mining equipment that locks the operational frequency and voltage. This restriction deliberately limits the hardware's efficiency, compelling users to purchase upgraded models in subsequent years to maintain profitability. My independent research aimed to counteract this limitation by enhancing the efficiency of mining hardware. I developed a program capable of optimizing the voltage and frequencies of the chips. This software not only manages multiple miners simultaneously but also equips operators with valuable data to maximize their hardware's potential and extend its viable lifespan.

2. Related Work

Another attempt to increase cryptocurrency miner efficiency was switching between mined cryptocurrencies to maximize profit (Yuen, Lau, & Ng, 2020). Additionally, others have performed research on undervolting and overclocking graphics card mining equipment (Shuaib, Badotra, Khalid, & Algarni, 2022). However, very little academic research has been done into applying similar techniques to ASIC based cryptocurrency mining equipment.

3. Process Design

All modern Bitcoin cryptocurrency miners function using a similar operational framework. Typically, each mining unit is equipped with three hashboards and an integrated power supply that delivers direct current to these hashboards. A control board distributes tasks to each hashboard, and every hashboard incorporates up to 126 ASIC chips arranged in series. The chips operate under a constant voltage provided by the manufacturer's firmware, ensuring that each chip consistently runs at a predetermined frequency.

In initiating my design process, the first step involved selecting a custom firmware capable of handling non-standard voltages and frequencies. After conducting thorough research, I opted for a firmware developed by Luxor. This choice was driven by its development in the USA and the inclusion of an API essential for the functionality of my program. The firmware also allows the user to view statistics and other information via a web interface (Figure 1).

For my research project, I established a hardware setup using a Bitmain S19 miner located off-campus. This setup included a remotely accessible power meter (Figure 2) and a VPN, enabling me to conduct experiments from the University of Virginia campus. It's important to note that UVA prohibits the use of campus electricity for operating cryptocurrency miners. I wrote my command line program in python and started by adding functions that would allow my program to interact with the Luxor firmware's API. The program interface is shown in Figure 4.

After implementing functions to retrieve and set API data, I commenced development on a tuning algorithm. Under its default optimal settings, the power supply delivers 14.4 volts of direct current. Leveraging the API, my program identifies and configures the power supply to its minimum viable output, which was 13.86 volts for the test unit in question. This adjustment enhances the efficiency of the operational ASIC chips, albeit at the expense of their stability.

Due to the phenomenon known as the silicon lottery, each chip exhibits unique characteristics, specifically a different maximum stable frequency and performance at a given adjusted voltage. To determine these optimal frequencies, my program initially sets a very low, yet stable frequency and records the baseline performance for each individual chip. Subsequently, it incrementally increases the frequency, carefully monitoring and recording the highest frequency at which each chip can operate without any degradation in performance compared to the baseline measurement.

After determining all the chip frequencies, the program commits this data to a pickle file and transitions into a continuous state of tuning and monitoring. This ongoing process allows the program to make adjustments in response to any stability changes caused by fluctuations in temperature or extended periods of operation. Should the program be closed and subsequently restarted, it intelligently recognizes pre-existing data for tuned miners, thereby eliminating the need to repeat the tuning process as shown in Figure 5.

The program with or without monitoring mode. In either case, a detailed tune log for each miner being tuned will be written to a text file (Figure 7). This allows multiple units to be tuned simultaneously without an overwhelming number of print statements to the terminal window. If the tuner is launched in monitoring mode, the terminal window will display various statistics in the terminal window (e.g. number of miners, temperature statistics, etc.) as can be seen in Figure 6.

4. Results

Initially, the results were rather underwhelming due to a range of bugs affecting performance. The primary issues stemmed from problems with the API and VPN, which extended the tuning process to more than 12 hours. Additionally, the per-chip tuning did not initially seem to enhance efficiency. Despite these challenges, I eventually discovered several methods to improve the tuning process. By executing various API commands concurrently or by grouping individual commands, I was able to save significant time. Furthermore, I improved the results from per-chip tuning by limiting the frequency spread on a per-hashboard basis.

I found that excessive frequency variations between neighboring chips and domains could lead to voltage imbalances, thereby causing instability across the hashboard. To address this issue, I implemented a strategy where the frequency difference between the highest and lowest chip on each board was capped at less than 25 MHz. It is important to note that each hashboard exhibits different performance characteristics; therefore, this frequency limitation was applied individually per hashboard rather than uniformly across the entire miner. This targeted approach proved to be more effective in stabilizing the system and enhancing overall performance.

After implementing several improvements, the tuning process of the program led to a significant reduction in power consumption, with a measured decrease of 280 watts at the wall. This adjustment has enhanced the unit's efficiency by 8%. Consequently, there has been an 18% increase in profitability, specifically when calculated using the electric rates in Charlottesville. The recorded data can be seen in Figure 3.

5. Conclusions

Enhancing the efficiency and profitability of older mining equipment is crucial for two key reasons: reducing the environmental impact associated with electricity consumption and minimizing electronic waste of the cryptocurrency mining industry by prolonging the life cycle of these units. This dual approach not only addresses immediate ecological concerns but also contributes to the sustainable use of technological resources in the mining industry.

6. Future Work

For this program to gain widespread acceptance and usage, several enhancements are necessary. First, the interface requires significant improvements to enhance user experience and accessibility. Additionally, it is crucial to conduct testing across various miner models to ensure broader applicability. Currently, the program operates exclusively with cryptocurrency miners that possess precisely three hashboards. To cater to a wider range of devices, it must be modified to support miners with varying numbers of boards. Moreover, the development of an enhanced status dashboard would be beneficial. This dashboard should clearly display the current tuning status of each miner being adjusted, providing users with essential real-time information.

Additionally, there is a fundamental issue with the perpetual tuning feature once the tuning process is completed. It decreases frequency, but never increases it. This means that as temperatures vary throughout the day, the miner will settle into a state based on the worst conditions. A useful future addition to this program would be a system to increase frequency based on temperature and other factors, so the miner is running in its most efficient possible state regardless of the environment.

7. UVA Evaluation

The foundational computer science courses at the 1000 and 2000 levels, particularly those that covered Python, proved to be invaluable for this project. Furthermore, the advanced software development class was instrumental in enhancing my understanding of good coding practices, which were directly applicable to this project. Additionally, the knowledge acquired in CS 4501: Cryptocurrency, has also been relevant and useful.

8. Acknowledgements

Thanks to my technical advisor, Professor Bloomfield, for all his advice and feedback on this research, and to my company, Manifold Mining, for supplying the hardware and electricity required for this experiment.

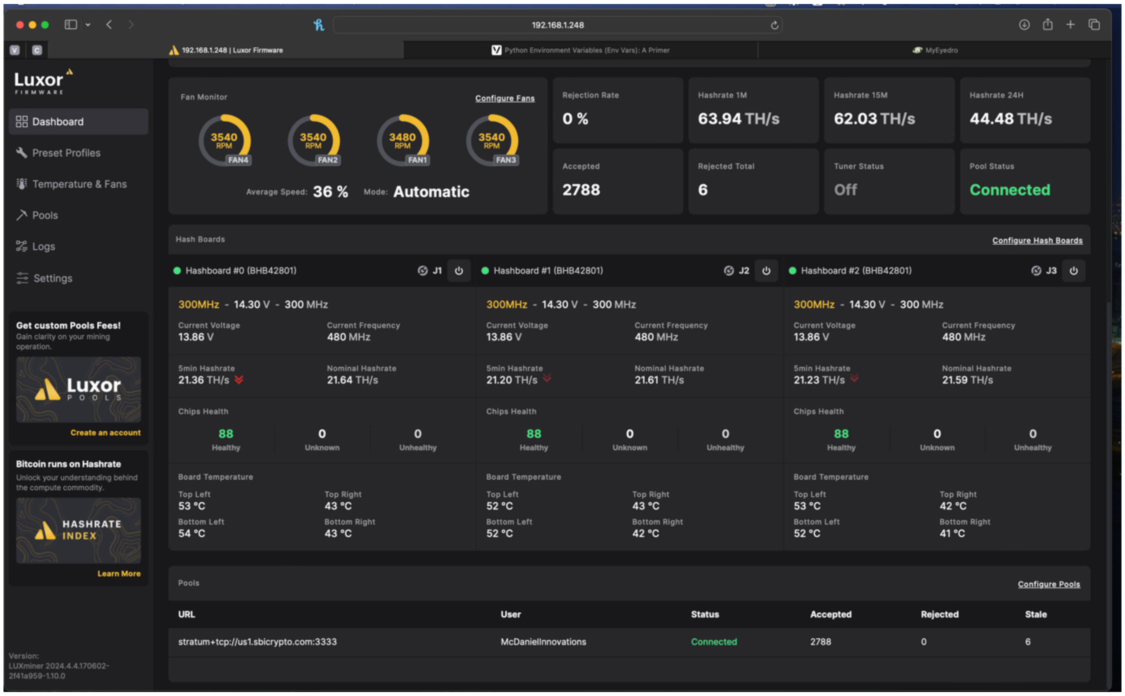

Figure 1: Luxor Web Dashboard for S19

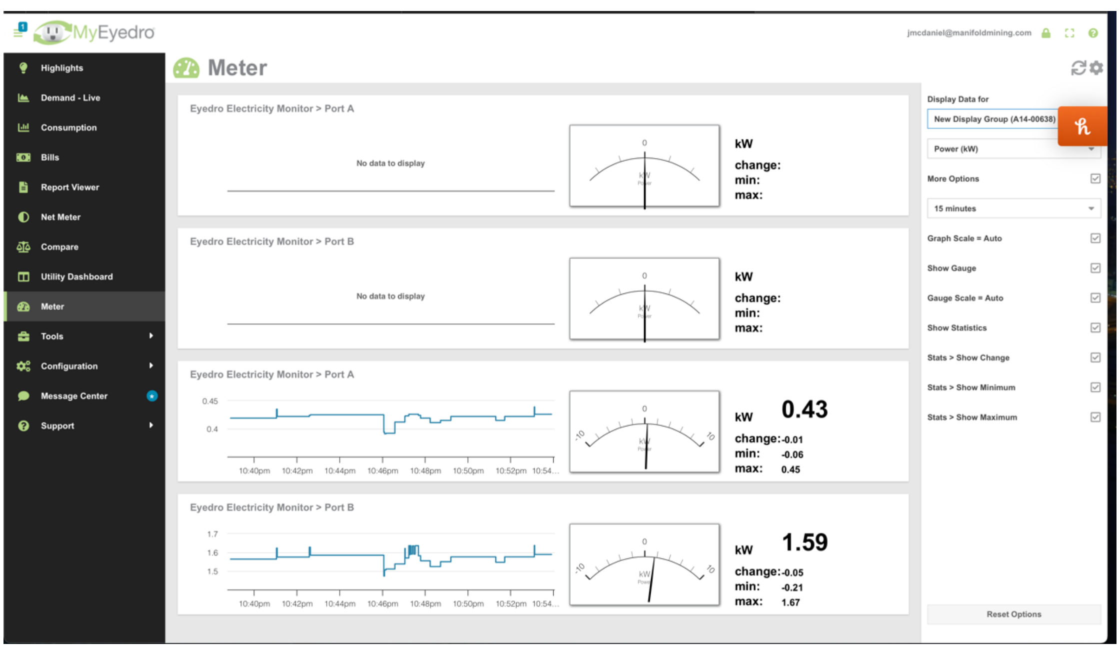

Figure 2: Remote Power Meter (Eyedro) for S19

Stock	Wattage	Hashrate	Efficiency	Profit	Efficiency increase	Profit Increase		average freq	voltage		Power Cost	dollar per TH
Normal	3080	91.6	33.6244541	$ 0.28				675	15.8		$ 0.13	$ 0.11
Low Power	1820	68	26.7647059	$ 1.67				500	14.37			
With tuning	1550	62.29	24.8836089	$ 1.89	7%	14%		545	14.4			
	1540	62.75	24.5418327	$ 1.97	8%	18%						

Figure 3: S19 Power Draw and profit calculation information

```
jacobmcdaniel@MacBook-Pro-3 Independent-research % python3 main.py
There are 1 compatible miners on the network
Perpetual Tune Mode = 1, Monitor and Tune Mode = 2
```

Figure 4: Program Menu

```
There are 1 compatible miners on the network
Perpetual Tune Mode = 1, Monitor and Tune Mode = 2
1
Enter perpetual tune
Loading saved data...
Data loaded successfully!
```

Figure 5: Tuning data recovery

```
Local Time: 12:35:32


To manually pause miners, hold the "S" key for 3 seconds.
To manually resume mining, hold the "W" key for 3 seconds.

To rescan the network for miners after network changes, hold the "N" key
To clear the log, hold the "M" key

Number of miners monitored: 1
Highest temp: 51 C
Average temp: 45 C
Lowest temp: 39 C
```

Figure 6: Temperature monitoring dashboard

```
192.168.1.130-log.txt
18:13:43: Current Voltage: 13.863025466628432
18:13:44: Current Freq: 400.0
18:13:47: Current Chip Health: True
18:20:52: miner settled
19:01:00: Baseline Scores:
19:01:00: [98.0, 96.0, 97.0, 101.0, 100.0, 100.0, 99.0, 100.0, 103.0, 101.0, 104.0, 101.0, 99.0, 99.0, 98.0, 100.0, 100.0, 98.0, 99.0, 98.0, 102.0, 99.0, 99.0, 100.0, 101.0, 102.0, 97.0, 98.0, 100.0, 101.0,
101.0, 97.0, 97.0, 100.0, 98.0, 99.0, 102.0, 100.0, 104.0, 99.0, 100.0, 101.0, 96.0, 102.0, 103.0, 99.0, 102.0, 102.0, 100.0, 102.0, 104.0, 103.0, 99.0, 103.0, 102.0, 100.0, 100.0, 101.0, 100.0, 104.0, 97.0,
97.0, 100.0, 104.0, 101.0, 102.0, 100.0, 99.0, 99.0, 104.0, 99.0, 98.0, 103.0, 103.0, 102.0, 99.0, 98.0, 100.0, 101.0, 100.0, 96.0, 101.0, 103.0, 99.0, 102.0, 100.0, 99.0, 103.0]
19:01:00: [99.0, 101.0, 101.0, 103.0, 102.0, 100.0, 95.0, 102.0, 98.0, 101.0, 102.0, 102.0, 102.0, 102.0, 101.0, 101.0, 98.0, 101.0, 98.0, 99.0, 98.0, 99.0, 99.0, 100.0, 101.0, 101.0, 103.0, 98.0, 102.0,
102.0, 102.0, 100.0, 97.0, 96.0, 99.0, 103.0, 98.0, 100.0, 99.0, 98.0, 101.0, 102.0, 99.0, 100.0, 102.0, 105.0, 99.0, 100.0, 101.0, 99.0, 100.0, 103.0, 101.0, 96.0, 99.0, 99.0, 99.0, 95.0, 99.0, 98.0, 103.0,
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19:01:00: [95.0, 100.0, 100.0, 98.0, 99.0, 96.0, 96.0, 99.0, 104.0, 104.0, 100.0, 99.0, 101.0, 97.0, 94.0, 106.0, 101.0, 100.0, 104.0, 99.0, 98.0, 99.0, 101.0, 102.0, 103.0, 98.0, 100.0, 99.0, 105.0, 103.0,
100.0, 98.0, 102.0, 103.0, 100.0, 101.0, 102.0, 98.0, 101.0, 103.0, 98.0, 101.0, 95.0, 102.0, 100.0, 100.0, 102.0, 103.0, 103.0, 95.0, 99.0, 100.0, 103.0, 99.0, 102.0, 99.0, 103.0, 101.0, 100.0, 102.0, 103.0,
99.0, 101.0, 101.0, 104.0, 98.0, 101.0, 100.0, 93.0, 102.0, 100.0, 101.0, 99.0, 98.0, 100.0, 97.0, 100.0, 98.0, 97.0, 99.0, 102.0, 102.0, 99.0, 100.0, 105.0, 102.0, 95.0, 93.0]
19:12:11: Proposed frequencies:
19:12:11: [405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405,
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405, 405, 405, 405, 405, 405, 405]
19:12:11: [405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405,
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405, 405, 405, 405, 405, 405, 405]
19:12:11: [405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 390, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405, 405,
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405, 405, 405, 405, 405, 405, 405]
20:21:25: Waiting for chips to stabilize
20:21:36: Still waiting for chips to stabilize
20:22:26: Still waiting for chips to stabilize
20:23:32: Still waiting for chips to stabilize
20:24:31: Chips stabilized
20:24:31:
Tuning round complete!
```

Figure 7: Miner tune log

Works Cited

Shuaib, M., Badotra, S., Khalid, M., & Algarni, A. (2022). A Novel Optimization for GPU Mining Using Overclocking and Undervolting. Sustainability.

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