Phoenix Zombie Mining

Werner Almesberger
Linzhi Ltd.

July 11, 2021

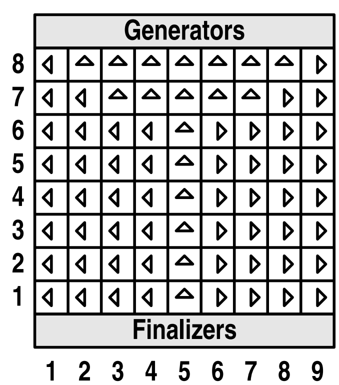
Linzhi Phoenix miners have 4.430 GB or 37'158'912 lines of DAG memory. Ethereum's DAG will grow beyond this size at the end of Ethereum epoch 439. This epoch should end around September 2021.[1]

We have implemented an experimental feature that will allow to mine beyond this point. The miner will then simply discard all tasks that would touch DAG locations outside the available memory. This approach was originally used by GPU miners to make it past Ethereum's DAG growth beyond 4 GB, and is known as "zombie-mining".

1 Zombie-mining

The Linzhi Phoenix implementation of zombie-mining distributes as much of the DAG that fits normally over the available chips. Then it adds a fake destination for the part of the DAG that lies outside available memory.

This fake destination routes tasks outside the NoC, where they will be discarded. The off-NoC destination depends on the position of the node at which the off-DAG address is generated, as shown in the following drawing:



We do not route tasks to the finalizers since they would consider each task they receive a final hash result, check it for meeting the desired difficulty, etc.

[1] According to `https://minerstat.com/dag-size-calculator`
Estimates of the exact time and date fluctuate wildly, at the time of writing still by several weeks.

2 Hashrate decay

Discarding tasks means that the hashrate of the miner is reduced. Since with each epoch the DAG grows a little larger than available memory, the hashrate also decreases with every new epoch (about every 4 days).

This table shows a first projection for the decay, based on the probability of a task to touch a part of the DAG beyond available memory, and thus be lost:[2]

Epoch	DAG÷memory ratio	Calculated efficiency (η)	Simulation
439	+0%	100%	100%
440	+0.18%	89.33%	91.53%
441	+0.35%	79.80%	83.16%
442	+0.53%	71.29%	75.27%
443	+0.71%	63.69%	67.91%
444	+0.89%	56.90%	61.01%
445	+1.06%	50.83%	54.67%
446	+1.24%	45.41%	48.98%
447	+1.42%	40.57%	43.93%
448	+1.60%	36.24%	39.45%
449	+1.78%	32.37%	35.06%

Epoch 449 will end about 40 days after the start of epoch 440, the beginning of zombie-mining.

3 Vacant capacity

In the above table, simulation results are slightly better than the calculated efficiency. This is mainly because the miner normally operates in a congested condition where a number of tasks (less than 10%) is routinely lost inside the system.[3] If tasks are lost due to exceeding the DAG, this reduction leads to a decrease of congestion, and thus of congestion loss.

Since peak performance is reached at moderate congestion loss, zombie-mining performance can therefore be improved by increasing the rate at which tasks are generated. The following table shows simulated efficiency if compensating for all the tasks lost due to zombie-mining:[4]

[2] Calculated efficiency $\eta = \left(\frac{\text{available\_memory}}{\text{DAG\_size}}\right)^{64}$

[3] This may seem wasteful, but actually results in a higher hash rate than could be obtained with a lower load. The reason is that reducing congestion also increases the number of times part of the system is idle. We therefore try to operate the miners at a point where losses and idleness are balanced to produce an optimal overall performance.

[4] Using the same task generation speed, the ratio between work done when zombie-mining and the work done without zombie-mining is $\mathrm{w_{zombie}} = \eta + (1-\eta)\eta = 2\eta - \eta^2$. The adjusted generation speed is thus $\mathrm{g_{adj}} = \mathrm{g_{normal}} \cdot \mathrm{w_{zombie}}^{-1}$, and the adjusted efficiency is $\eta_{\mathrm{adj}} = \eta \cdot \mathrm{w_{zombie}}^{-1}$.

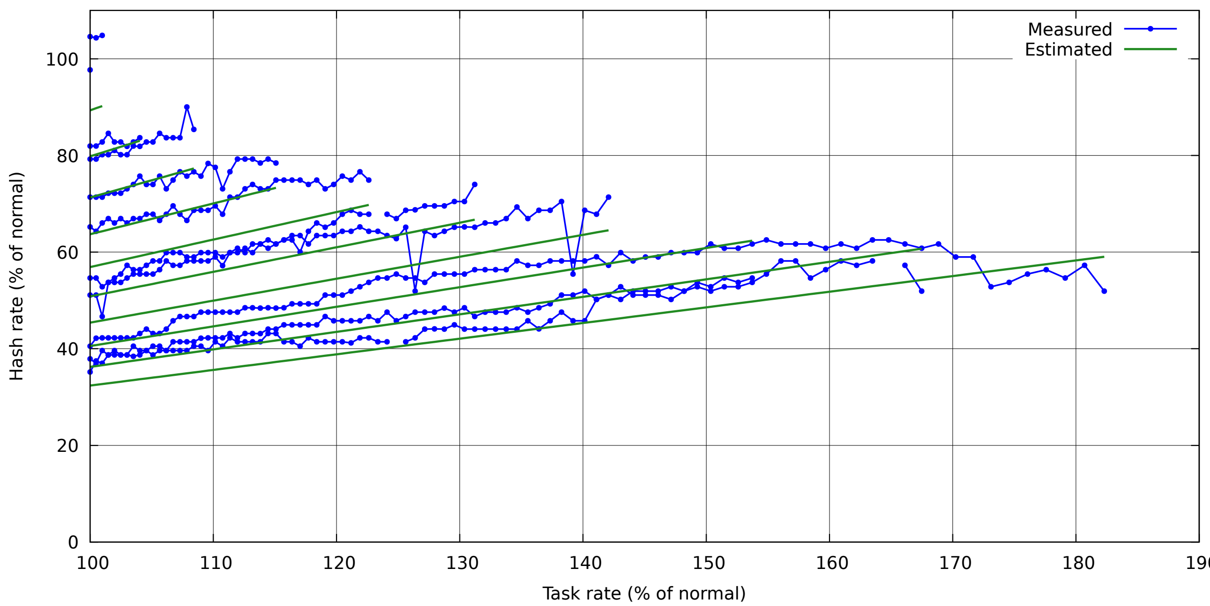
Epoch Epoch	Work ratio (w_{zombie})	Adjusted for w_{zombie} Calculated efficiency (η_{adj})	Simulation
439	100%	—	—
440	98.86%	90.36%	92.27%
441	95.92%	83.20%	85.56%
442	91.76%	77.69%	79.98%
443	86.81%	73.36%	75.57%
444	81.42%	69.88%	71.41%
445	75.82%	67.04%	67.51%
446	70.20%	64.69%	64.29%
447	64.68%	62.72%	61.02%
448	59.35%	61.06%	57.73%
449	54.27%	59.66%	53.56%

Since efficiency decays more rapidly than the work performed by the miner,[5] we cannot compensate for all the losses, but a substantial improvement is still possible.

Simulation results show a drop towards later epochs. This is probably caused by the then very high task rate (g_{adj}) causing losses to occur in parts of the system where they are normally rare.

4 Experimental verification of hash performance

Zombie-mining has been implemented and verified on real hardware. The following graph shows the results for ten epochs past the end of the DAG, each with a parameter sweep for the task rate:



[5] For example, for $\eta = 90\%$, 10% of all tasks are eventually lost, but this will happen on average after having passed 90% of the 64 rounds. Thus, the work is only reduced by $10\%^2 = 1\%$.

The x-axis shows the task generation rate, which goes from the rate without compensation for zombie-mining losses (g_{normal}, 100%) to the rate at which the work not performed due to losses is fully compensated (g_{adj}).

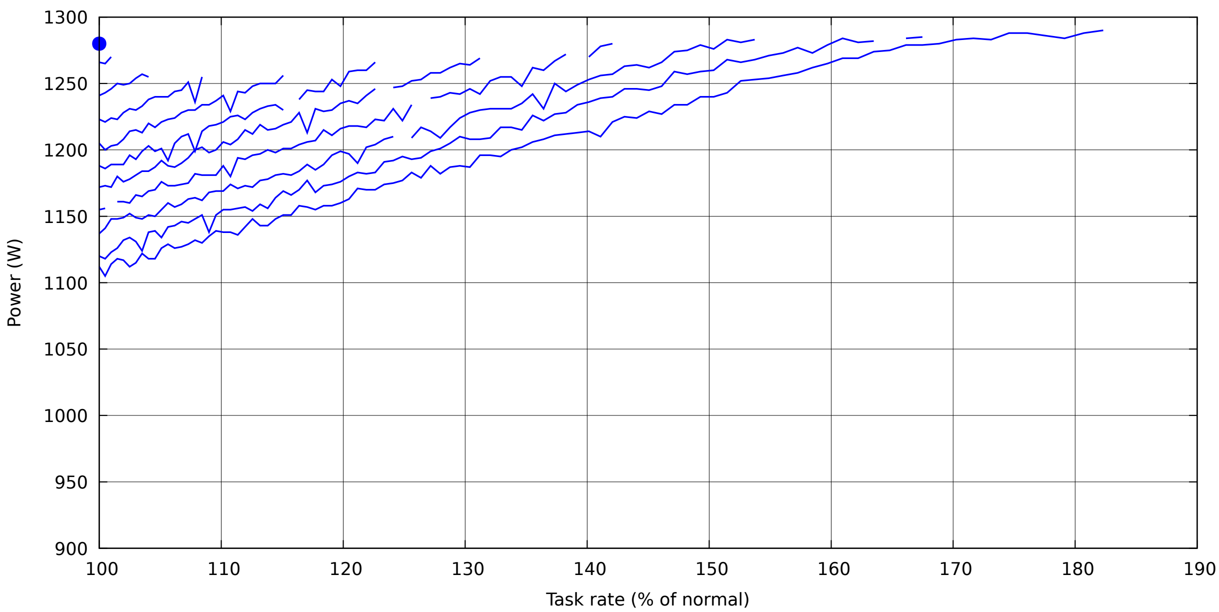
The green lines show the theoretical performance (going from η to η_{adj}). The purple dots show the measured hash rate.[6]

The experimental results show the expected trend. There are some anomalies, where entire epochs appear to be offset by about 10%. This may be caused by the experiment setup, which used DAG sizes and contents different from the real epochs.

One can also see that, as the simulation results suggested, going faster than about 160% of the original task rate does not improve performance.

5 Experimental data for power consumption

During the mining experiment, we also monitored the power consumption of the hashboard:



This board has a typical power consumption of 1280 W (input power from the PSU). The measured power consumption corresponds to the work done by the miner for any epoch and generation speed combination. Note that most of the power consumption is fixed and only a small part depends on the amount of mining work done.

Most importantly, even at the most aggressive task rate increase, power consumption is only slightly higher than before zombie-mining.

6 The occasional outlier or missing data point is caused by the miner not restarting with full performance after re-configuration. In normal mining operation, large performance deviations are detected and automatically corrected, but the tool used for the experiment lacks such functionality. These excursions were not caused by zombie-mining.

6 Generation rate adjustment

We have seen that the generation rate should be increase when zombie-mining, to compensate for under-utilization of miner resources. We have also found that attempting to compensate for all the losses leads to lower performance than compensating for only part of them.

We therefore introduced a new configuration variable **ZOMBIE_COMP**, in Configuration > Slot N, that determines how much compensation will be applied. Valid values are in percent and range from 0 to 100. The default is 80%.

7 Experiment with actual future DAGs

In an improved experiment, we set up a dummy pool that would tell miners to mine future epochs. With this, we obtained the following results, using an 80% setting for **ZOMBIE_COMP**):

Epoch	Hash rate (MH/s)		Ratio	
	Slot 0	Slot 1	Slot 0	Slot 1
439	1271	1304	100%	100%
440	1183	1178	93%	90%
441	1081	1112	85%	85%
442	1004	1028	79%	78%
443	933	945	73%	72%
444	878	926	69%	71%

The results are close to the calculated efficiency ((η_{adj})). As expected, none of the large shifts observed in the experiments using an only approximate DAG occurred.

8 Alternatives to zombie-mining

Zombie-mining is not the only option when the ETH DAG outgrows available memory. Alternatively, Ethash-based coins with a smaller DAG can be mined. Ethereum Classic (ETC), Callisto (CLO), Expanse (EXP), QuarkChain (QKC), and Ubiq (UBQ) have all been tested with our miners and we provide templates for pools operating these coins.

Metaverse (ETP) has also been successfully mined but we have not made templates for it yet. Note that Metaverse is in a transition stage with a major revision planned by the end of the year.

A comparison of the mining profitability of Ethash-based coins can be found at `https://whattomine.com/coins?e4g=true`. Among these coins, ETC is currently the most profitable, in recent months moving between 50% to close to 100% of ETH profitability. Typically, it is in the 60% to 80% range.

Since the DAGs of all these coins grow, too, they will eventually also exceed the available memory. Based on current chain growth estimates, for QuarkChain and Callisto this is expected to happen in 2023. Expanse and Ethereum Classic would be next, in 2026. Ubiq would follow in 2034.

9 Conclusion

Linzhi Phoenix miners mining the Ethereum coin will run out of DAG memory around September 2021, and from then on need to use a reduced-performance mode called zombie-mining. Zombie-mining is implemented in the latest firmware[7] and engages automatically when needed.

We have examined performance when zombie-mining by calculating a simplified theoretical model, simulation, and running experiments on Linzhi miners. The results of all three are consistent with each other, show that zombie-mining works, and is likely to yield better profit than mining an alternative coin for about a month.

Furthermore, we discussed which alternative coins could be mined, and which ones we expect to support in the near future.

[7] fw-test-20210711-1936 or later.