Introduction to Blockchain, Cryptocurrencies and Smart Contracts
(CS 765)
Assignment 1

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Design choices

2.

Q) What are the theoretical reasons for choosing the exponential distribution for the interarrival between transactions generated by any peer?

Ans. The generation of a transaction between two nodes is a rare event which can thus be modelled by the poisson distribution. We also know that the distribution of interarrival time between two events generated from the poisson distribution is exponential. Thus it makes sense to choose exponential distribution to model the interarrival time between transactions generated by a peer.

4.

Q) Random sampling of network with justification of chosen distribution.

Ans. We are using the Power-Law degree distributed graph to simulate a real world P2P cryptocurrency network simulation. Real world cryptocurrency networks have been studied to have this distribution which is also called a Scale-free distribution. Scale-free networks are a type of network characterized by the presence of large hubs. For an undirected network, we can just write the degree distribution as:

$$\boxed{P_{\text{deg}}(k) \propto k^{-\gamma}}$$

We can see how it is scale-free since it decays exponentially and having a multiple of the number of nodes would just alter the proportionality constant and not the relationship above.

These papers discuss the degree distribution of the Bitcoin network and find it to be Power Law distributed:

- https://www.researchgate.net/publication/262562539_Exploring_the_Bitcoin_Network
- https://arxiv.org/pdf/2003.06068.pdf

We use the implementation for random sampling from the networkx python library. The hyperparameter p (Probability of adding a triangle after adding a random edge) is used as 0.46 as noted in the second paper. The parameter m (the number of random edges to add for each new node) has been taken as 2 for our simulations.

5.

Q) Why is the mean of d_{ij} inversely related to c_{ij}? Give justification for this choice.

Ans. c_{ij} is the link speed between nodes i and j in bits per second, and d_{ij} is the queuing delay at node i to forward the message to node j. Queuing delay is the time a message has to wait at the node before being transmitted. The waiting time would proportionally decrease as link speed is increased as that would mean that the earlier messages are sent in a proportionally lesser time. This justifies the inverse relationship between d_{ij} and c_{ij}.

7.

Q) Justify the chosen value for T_k.

Ans. The mine delay should be in comparison a large value to the network delays or the interarrival times for transactions as mining is supposed to be a time and computation heavy process. We took interarrival time for mining blocks as 50 so that T_k for blocks could go upto 500 with 10 nodes as the hashing powers were around 10% on average.

Visualization & Experimentation

- **Variation with change in number of nodes (n):**

We plot the mining ratios wrt to fast/slow nodes and with hashing powers in the form of scatter plots. As the number of nodes is increased, the relationship between hashing power and mining ratio is apparent. More hashing power means that a larger percentage of blocks mined are accepted to the longest chain. Increasing n increases the number of transactions created while the number of blocks in the longest chain decreases.

- **Variation with change in fraction of fast nodes (z):**

As z increases, more blocks are mined for a given simulation time, competition increases between nodes.

- **Variation with change in Transaction interarrival time (Ttx):**

As Ttx increases, less transactions are generated. This is visible from the average number of transactions in the blocks which are mined.

- **Variation with change in Mining delay (Tk):**

As Tk increases, lesser blocks are mined. This is apparent from the longest chain length at the end of the simulation.

NOTE: The above trends are slightly visible from the experiment plots.

We can see over multiple plots that the fast nodes tend have a higher mined ratio if hashing powers are equal. Also, with increasing in hashing power the mined ratio increased as well.

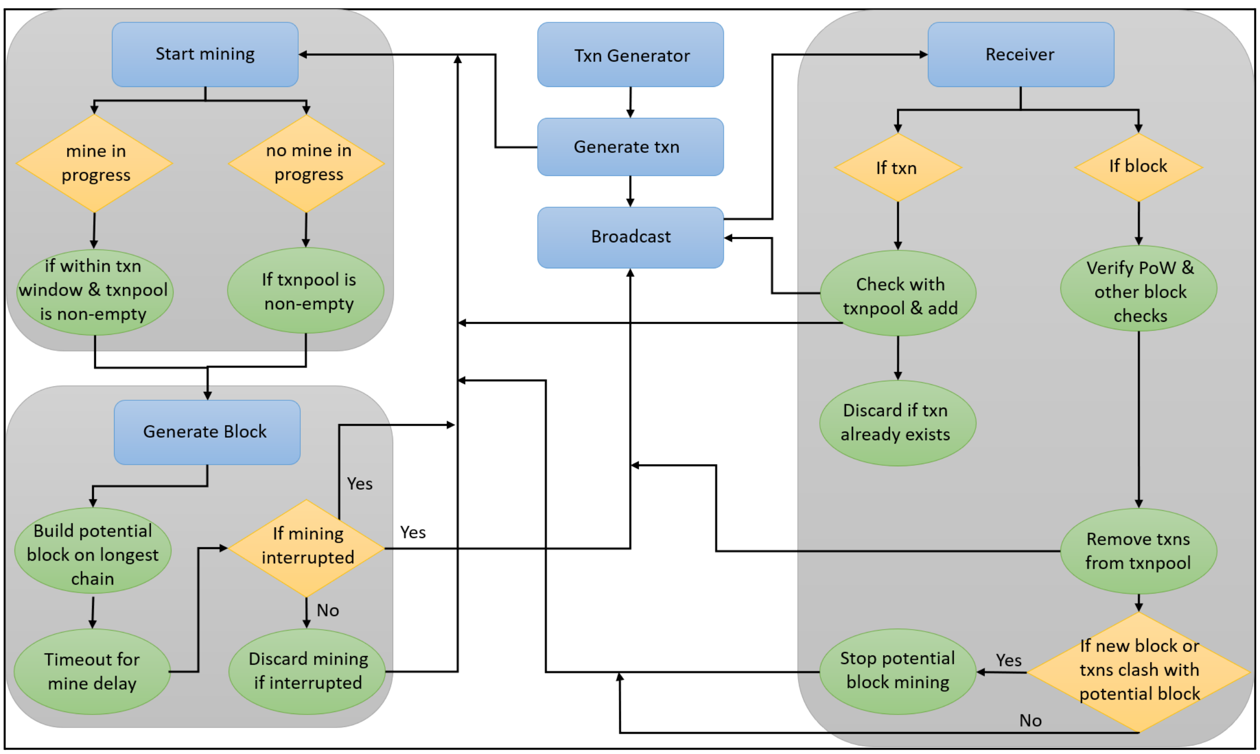
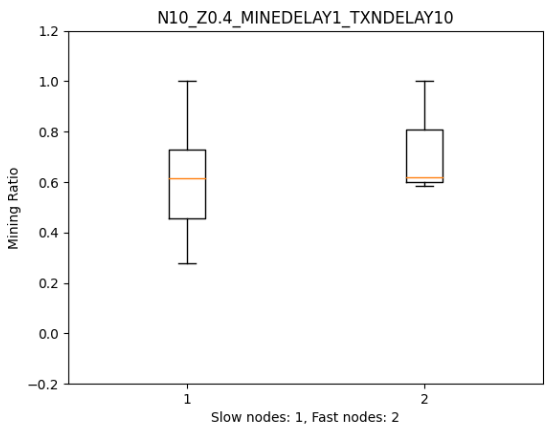
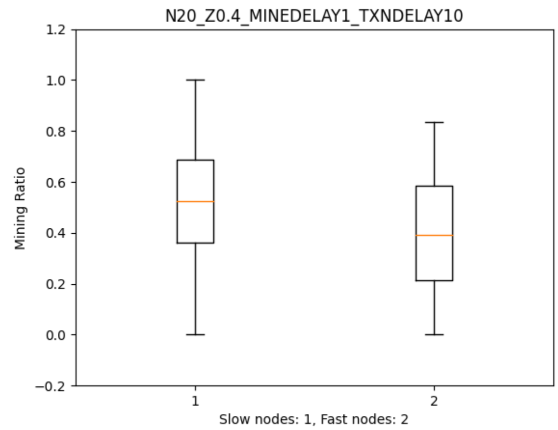


Figure: Design flowchart

The branches are very short in length wherever found, usually with a length of 1 or at max 2.

Changes in (n)


N10_Z0.4_MINEDELAY1_TXNDELAY10
Mining Ratio
Slow nodes: 1, Fast nodes: 2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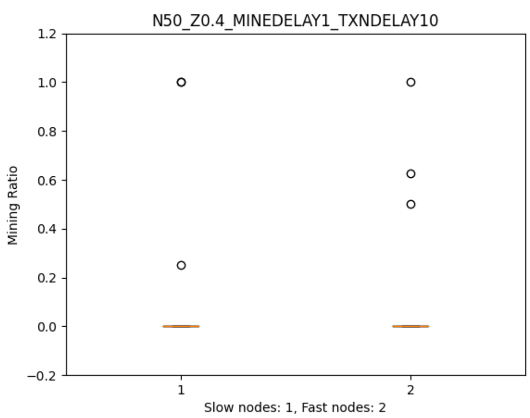
Mining Ratio
Slow nodes: 1, Fast nodes: 2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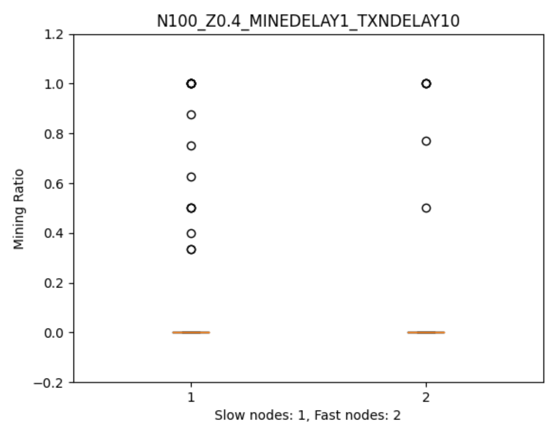
Mining Ratio
Slow nodes: 1, Fast nodes: 2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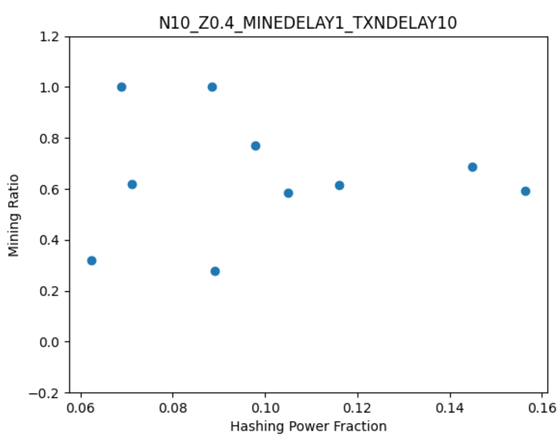
Mining Ratio
Slow nodes: 1, Fast nodes: 2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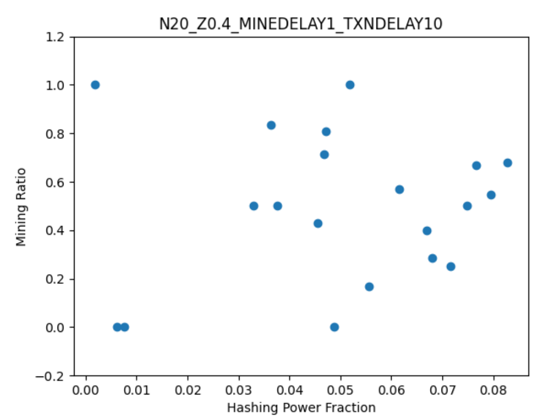
Mining Ratio
Hashing Power Fraction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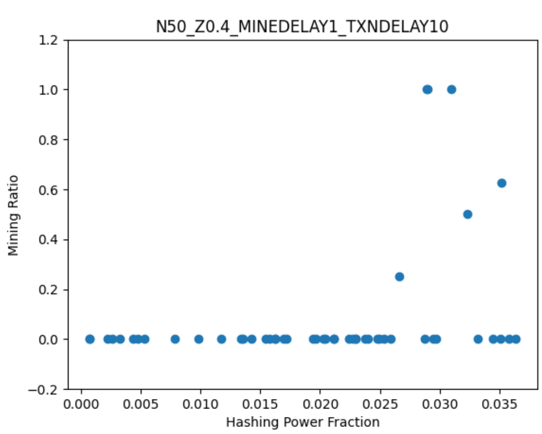
Mining Ratio
Hashing Power Fraction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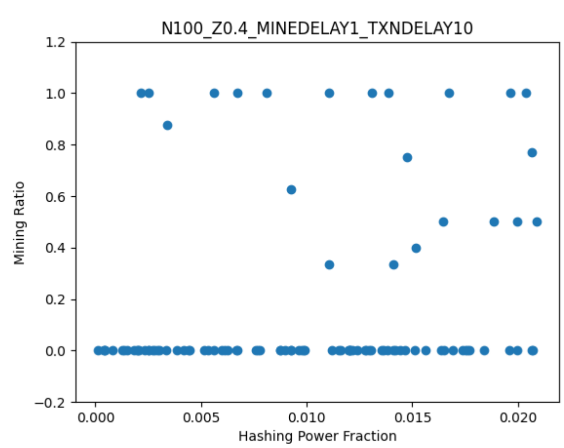
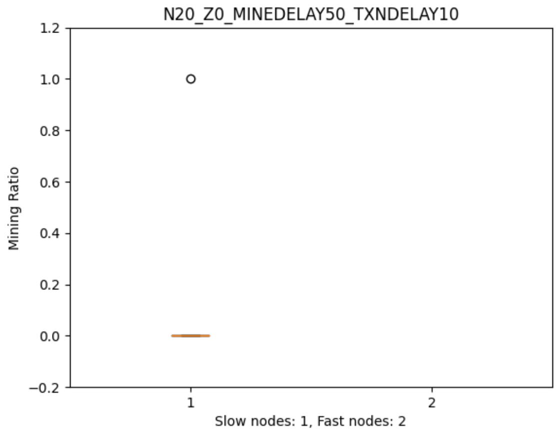
Mining Ratio
Hashing Power Fraction


N100_Z0.4_MINEDELAY1_TXNDELAY10
Mining Ratio
Hashing Power Fraction

Changes in (z)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Mining Ratio
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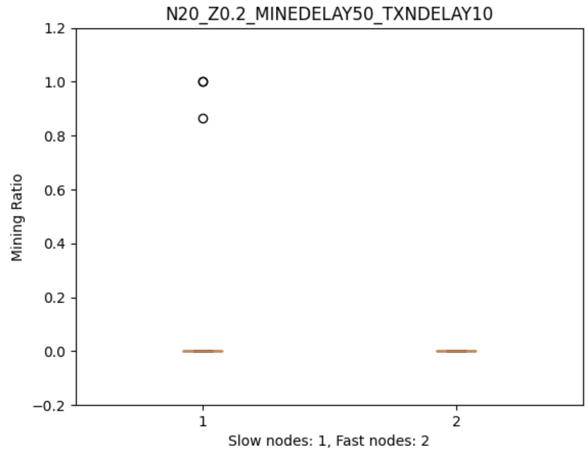
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Mining Ratio
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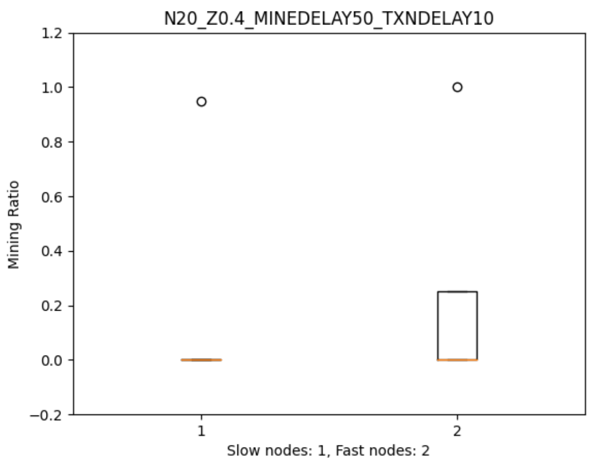
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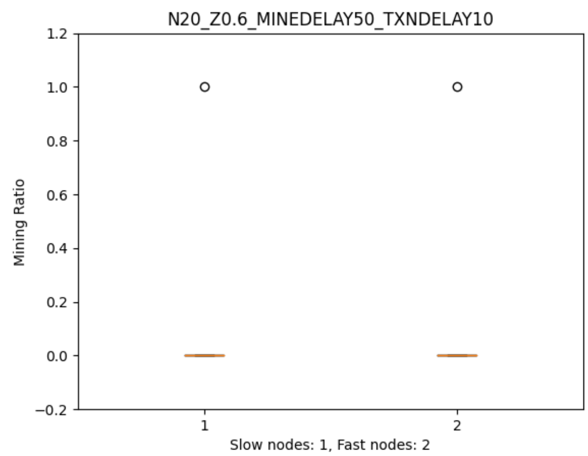
Mining Ratio
Slow nodes: 1, Fast nodes: 2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Mining Ratio
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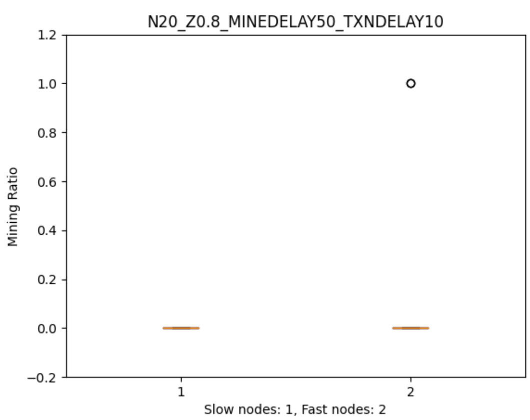
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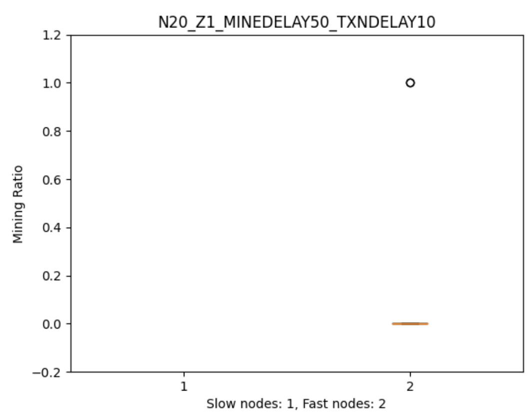
Mining Ratio
Slow nodes: 1, Fast nodes: 2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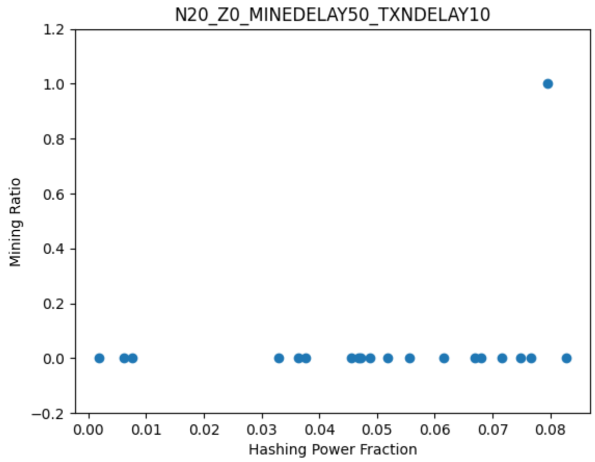
Mining Ratio
Slow nodes: 1, Fast nodes: 2


N20_Z0_MINEDELAY50_TXNDELAY10
Mining Ratio
Hashing Power Fraction
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
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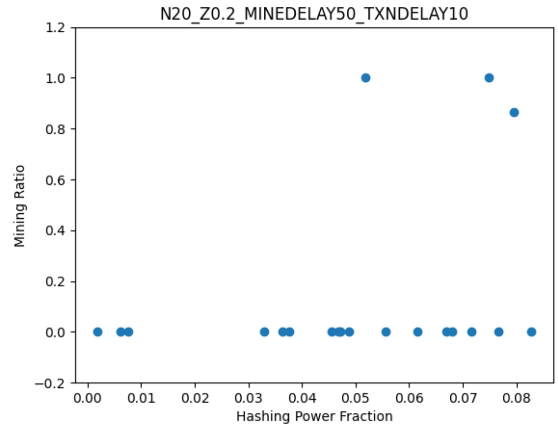
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Mining Ratio
Hashing Power Fraction
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0.8
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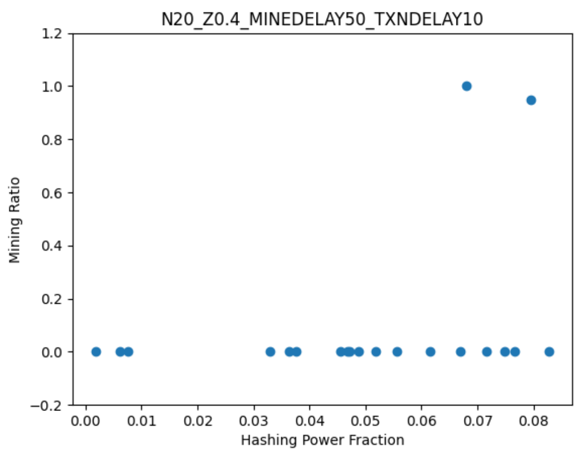
N20_Z0.4_MINEDELAY50_TXNDELAY10
Mining Ratio
Hashing Power Fraction
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1.0
0.8
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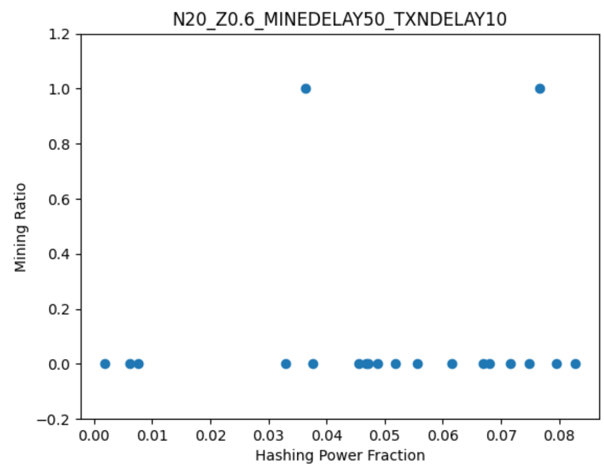
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Mining Ratio
Hashing Power Fraction
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1.0
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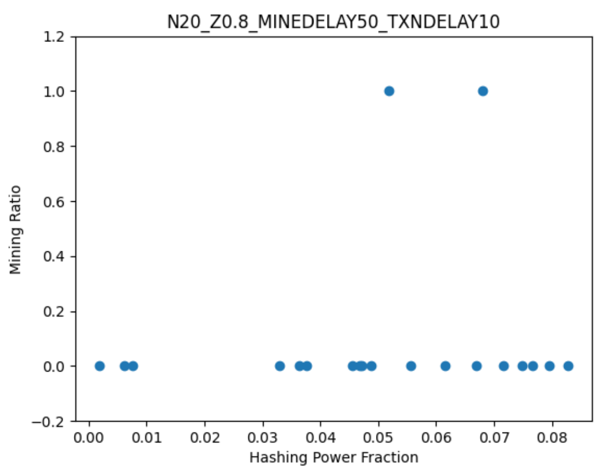
N20_Z0.8_MINEDELAY50_TXNDELAY10
Mining Ratio
Hashing Power Fraction
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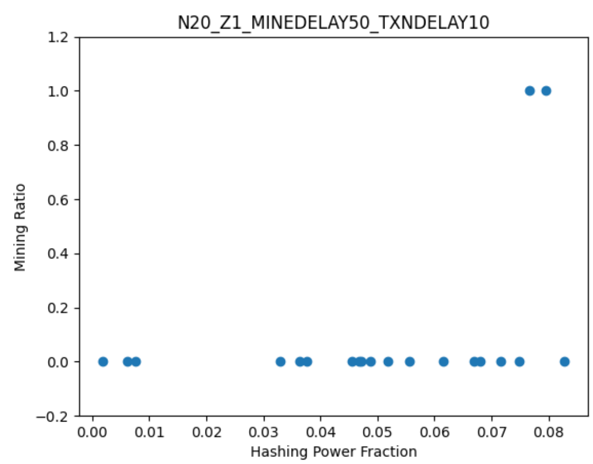
N20_Z1_MINEDELAY50_TXNDELAY10
Mining Ratio
Hashing Power Fraction
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1.0
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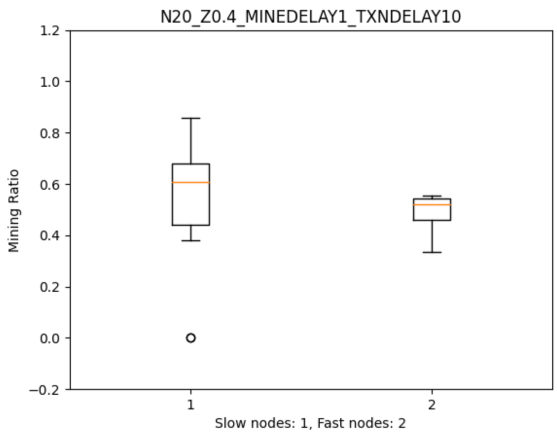
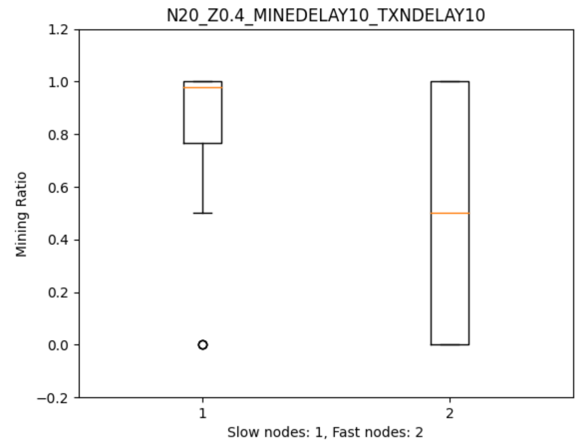
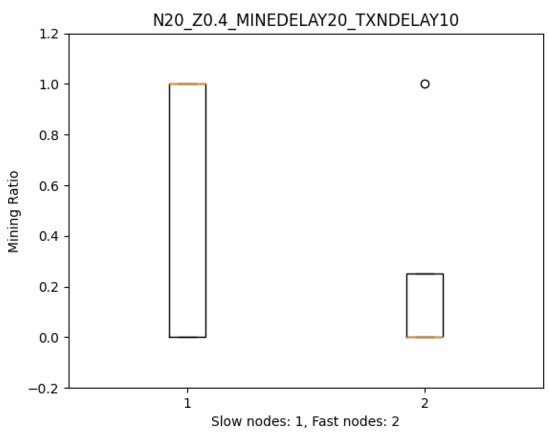
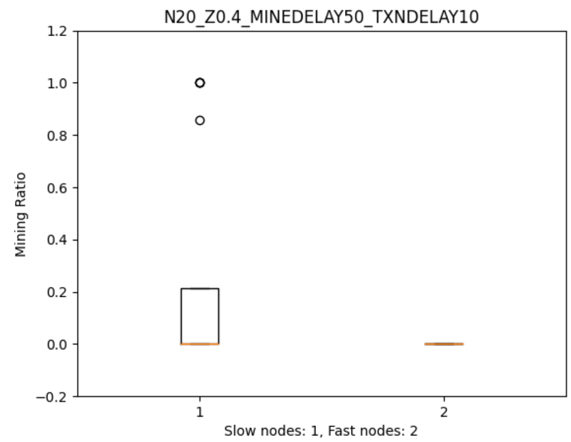
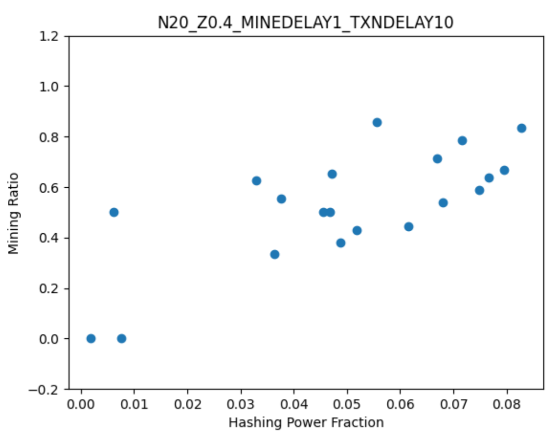
Changes in (Tk)

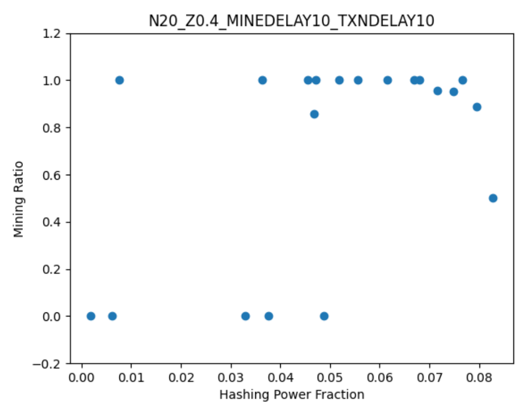


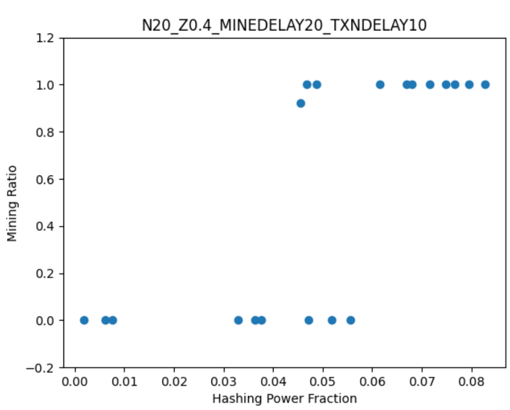


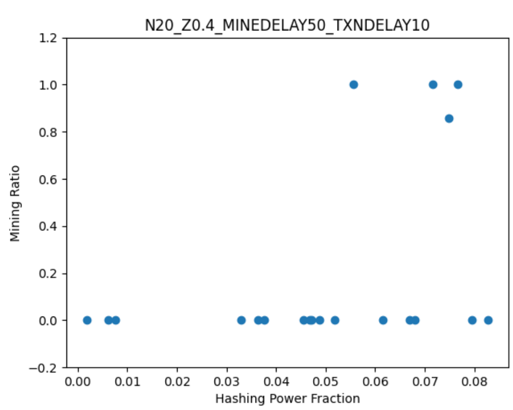












Changes in (Ttx)