2022-05-04

BCH Scaling Evaluation Report #1

Intent

The primary purpose of this performance evaluation is to determine how well the BCHN server and Fulcrum server perform when processing very large BCH blocks. The secondary purpose of this evaluation is to identify better techniques for future testing and evaluation; this includes recognizing pitfalls in the testing framework, identifying non-functional requirements around future tests, and edge cases in the testing framework, node software, and test subjects.

Testing Method

Execution of the test consists of a BCHN full node that receives blocks and transactions from a test block emitter, and is disconnected from any other peers/network. A Fulcrum server is then connected to the BCHN server. The emitter is a custom application designed to relay blocks and transactions at a programmable rate. The BCHN server is configured with a custom "ChainParams" configuration to accept and validate the test blockchain. The host machine is configured with a network time of around 1651113031, which is necessary to trigger the node out of IBD mode.

Before execution of the test, a custom blockchain was mined. This chain is derived from BTC/BCH mainnet block #144. 144 mainnet blocks were chosen because they allowed the chain enough blockheight to have all current BCH mainnet rules to be activated (including its Aserti32d DAA, which requires 144 blocks). The activation of all mainnet rules was targeted to ensure the code-paths followed during testing were as close to identical to the production environment.

Blocks #145 through #244 (inclusive) are empty blocks (only containing a coinbase) to establish spendable coins for use in testing (coinbase transactions may not be spent until they are 100 blocks old).

Blocks #245 through #254 are "fan-out" blocks, roughly 177MB in size and containing about 178k transactions. The fan-out blocks spend one output and generate 26 outputs each, and are approximately 1kB in size. The transactions in these blocks are heavily chained, meaning most transactions spend an output from a previous transaction from within the same block.

Blocks #255 through #259 are "steady-state" blocks, roughly 244MB in size and containing about 68k transactions. The steady-state blocks spend 25 outputs and generate 2 outputs each, and are approximately 3.5kB in size. The outputs spent in this

block are chosen from an equal distribution of the previous “fan-out” blocks. Most of these outputs are found from the first half of each fan-out block, and since blocks are sorted by canonical ordering, and UTXOs are stored sorted within LevelDB, many of the UTXOs spent will be found on nearby pages of the UTXO database. This is intended to render frequent cache-hits from the BCHN UTXO database, which should have a positive influence on performance. This test is hypothesized to render better results than UTXOs that are being spent from non-clustered pages of the UTXO database.

Blocks #260 and #261 are “fan-in” blocks, roughly 19MB in size and containing about 2k transactions. The fan-in blocks spend 64 outputs, generate 1 output each, and are approximately 9.4KB in size. The outputs spent in these two blocks are from blocks #255 and #256, respectively. These previous outputs are randomly distributed throughout the UTXO database, and are generally not clustered.

Blocks #262 through #266 are “steady-state” blocks, roughly 468KB in size and contain about 2k transactions. The steady-state blocks spend 1 output and create 2 outputs, and are approximately 226 bytes in size. These transactions spend amounts from the fan-in blocks, fan-out blocks, and previous steady-state blocks (when applicable).

When transmitting blocks from the test block emitter, blocks were submitted via RPC. Two variations of this test were executed:

1. Blocks were submitted via RPC without broadcasting transactions from the next block. This results in blocks that are filled with completely “unseen” transactions. These blocks were transmitted in rapid succession, each transmitted immediately after the BCHN server completed processing of the previous block.
2. Blocks were submitted via RPC roughly every 10 minutes. For each block, the next block’s transactions were transmitted to the node (via RPC) over the span of 10 minutes. Each transaction was submitted in an order that ensured their previous outputs were available. The percentage of each block “seen” was configured to be roughly 90% of the block’s transactions.

Additional proposed variations of this test consist of submitting the block via the Bitcoin Network Protocol (instead of RPC), and include transmitting transactions whose previous inputs have not yet been seen (in the case of chained/orphaned transactions, up to the maximum configured by the node). Additional variations may include varying the “seen percentage” from the 0% and 90% used above, with particular interest in 100% seen and submitting via the compact block protocol.

All tests were run on a 2020 MacBook Pro with 32 GB of 3733 MHz LPDDR4X Ram, a 2.3GHz Quad-Core Intel Core i7, with an Apple SSD AP2048N (M2 via PCIe) drive.

All outputs in the test blocks (after block #144) have canonical private keys. To derive a private key for an output, concatenate 16 bytes of zero with the output's block height (encoded as an 8-byte big-endian integer) and the output's amount (encoded as an 8-byte big-endian integer). An example implementation may be found here:

https://github.com/softwareverde/bch-scaling/blob/66c29e6dcf23f3fd58f5cf916048cd0948b14687/src/main/java/com/softwareverde/bitcoin/scaling/Main.java#L91

Results

We reviewed the timestamps associated with test block emission; unfortunately we did not log any timestamps to distinguish the difference between transaction-emission's start time and the full block-emission's start time; this has been corrected for future tests.

We reviewed the timestamps that BCHN logged to allocate new block.dat files as the block-processing start time, and used its update-tip log as the end time.

For Fulcrum, we used BCHN's end time for each block to assume Fulcrum's processing start time, and used Fulcrum's timestamps of its undo-block creation to measure its block processing end time. We also measured the script-hashes indexed per second, which occurs during block processing and transaction processing.

When evaluating results, excluded blocks before block #244 since they were set-up blocks with only a coinbase transaction.

Summary

0-Percent Seen

On average, when **0-percent** of the block was seen beforehand, **BCHN** was able to process:

Fan-Out Phase: (Blocks #245-254)

- **5833.4** transactions per second.
- 5833.4 inputs per second, and 151667.5 outputs per second.
- 5.794 MB per second.

Steady State One Phase: (Blocks #255-259)

- 1505.8 transactions per second.
- 37645.1 inputs per second, and 3011.6 outputs per second.
- 5.407 MB per second

Fan-In Phase: (Blocks #260-261)

- 708.7 transactions per second.
- 45354.7 inputs per second, and 708.7 outputs per second.
- 6.405 MB per second

Steady State Two Phase: (Blocks #262-266)

- Blocks processed in less than 1 second, stats could not be calculated

On average, when **0-percent** of the block was seen beforehand, **Fulcrum** was able to process:

Fan-Out Phase: (Blocks #245-254)

- 5535.2 transactions per second.
- 5535.2 inputs per second, and 143915.0 outputs per second.
- 5.498 MB per second.

Steady State One Phase: (Blocks #255-259)

- 38.8 transactions per second.
- 970.7 inputs per second, and 77.7 outputs per second.
- 0.139 MB per second

Fan-In Phase: (Blocks #260-261)

- 0.5 transactions per second.
- 29.9 inputs per second, and 0.5 outputs per second.
- 0.004 MB per second

Steady State Two Phase: (Blocks #262-266)

- 0.5 transactions per second.
- 0.5 inputs per second, and 0.9 outputs per second.
- 0.000 MB per second

90-Percent Seen

On average, when **90-percent** of the block was seen beforehand, **BCHN** was able to process:

Fan-Out Phase: (Blocks #245-254)

- 7407.6 transactions per second.
- 7407.6 inputs per second, and 192597.9 outputs per second.
- 7.358 MB per second.

Steady State One Phase: (Blocks #255-259)

- 5329.5 transactions per second.
- 133238.1 inputs per second, and 10659.1 outputs per second.
- 19.138 MB per second

Fan-In Phase: (Blocks #260-261)

- 2126.0 transactions per second.
- 136064.0 inputs per second, and 2126.0 outputs per second.
- 19.216 MB per second

Steady State Two Phase: (Blocks #262-266)

- Data is unavailable due to size of blocks and block emission delay

On average, when **90-percent** of the block was seen beforehand, **Fulcrum** was able to process:

Fan-Out Phase: (Blocks #245-254)

- 5462.8 transactions per second.
- 5462.8 inputs per second, and 142033.2 outputs per second.
- 5.426 MB per second.

Steady State One Phase: (Blocks #255-259)

- 60.9 transactions per second.
- 1522.3inputs per second, and 121.8 outputs per second.
- 0.219 MB per second

Fan-In Phase: (Blocks #260-261)

- 1.4 transactions per second.
- 92.4 inputs per second, and 1.4 outputs per second.
- 0.013 MB per second

Steady State Two Phase: (Blocks #262-266)

- 1332.2 transactions per second.
- 1332.2 inputs per second, and 2664.3 outputs per second.
- 0.286 MB per second

0-Percent Seen vs 90-Percent Seen Comparison Table

BCHN 0p vs 90p	Transactions Per Second	Inputs Per Second	Outputs Per Second	MB Per Second
BCHN Fan Out (0p)	5833.4	5833.4	151667.5	5.794
BCHN Fan Out (90p)	7407.6	7407.6	192597.9	7.358
BCHN Steady State 1 (0p)	1505.8	37645.1	3011.6	5.407
BCHN Steady State 1 (90p)	5329.5	133238.1	10659.1	19.138
BCHN Fan In (0p)	708.7	45354.7	708.7	6.405
BCHN Fan In (90p)	2126.0	136064.0	2126.0	19.216
Fulcrum 0p vs 90p	**Transactions Per Second**	**Inputs Per Second**	**Outputs Per Second**	**MB Per Second**
Fulcrum Fan Out (0p)	5535.2	5535.2	143915.0	5.498
Fulcrum Fan Out (90p)	5462.8	5462.8	142033.2	5.426
Fulcrum Steady State 1 (0p)	38.8	970.7	77.7	0.139
Fulcrum Steady State 1 (90p)	60.9	1522.3	121.8	0.219
Fulcrum Fan In (0p)	0.5	29.9	0.5	0.004
Fulcrum Fan In (90p)	1.4	92.4	1.4	0.013
Fulcrum Steady State 2 (0p)	0.5	0.5	0.9	0.000
Fulcrum Steady State 2 (90p)	1332.2	1332.2	2664.3	0.286

Miscellaneous Observations

After the 0-percent transaction broadcast runs, we saw BCHN take upwards of 28 seconds to shutdown after a sigkill command was given. The shutdown time for BCHN during the 90-percent broadcast run was not measured. Shutdown times of Fulcrum were not measured.

Further Research

Next recommended steps for continued testing is to create a chain with blocks roughly the size of current mainnet blocks to determine a baseline of comparison.

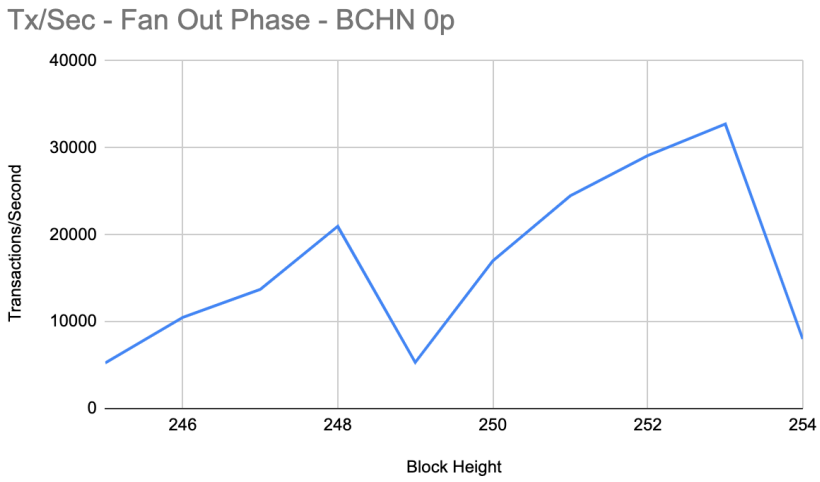
Additional next steps would be to connect a wallet application (i.e. Electron Cash) to Fulcrum while running through the tests, with the wallet containing variable amounts of affiliated private keys/transactions.

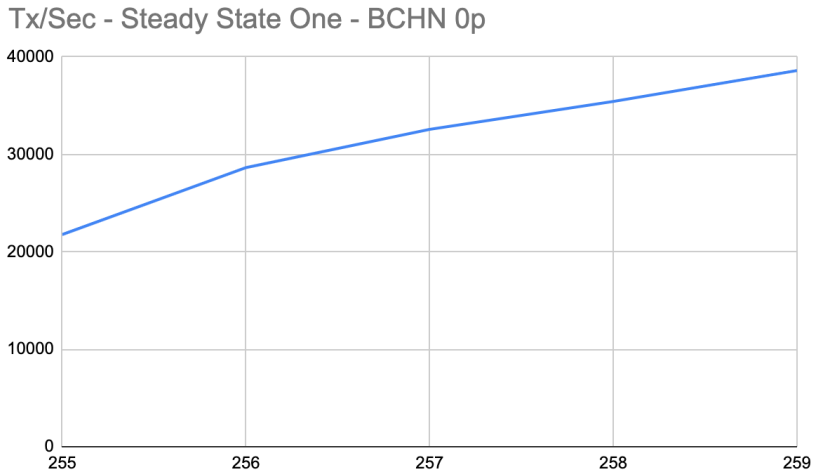
License

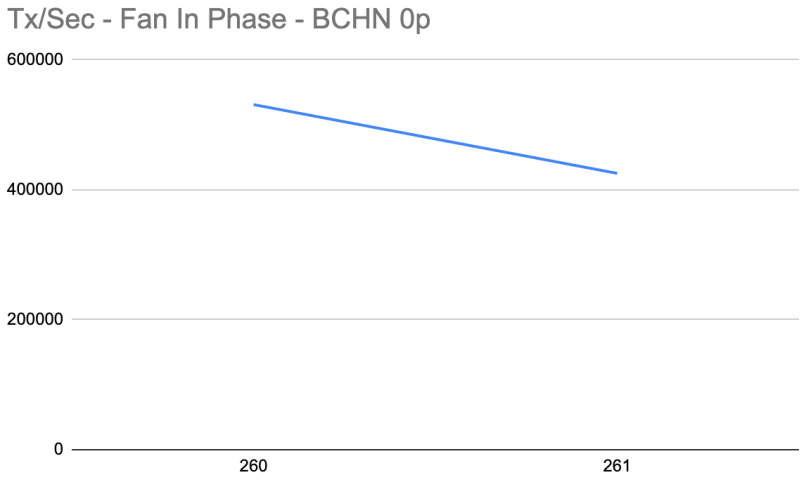
Code used to generate the above results may be found:

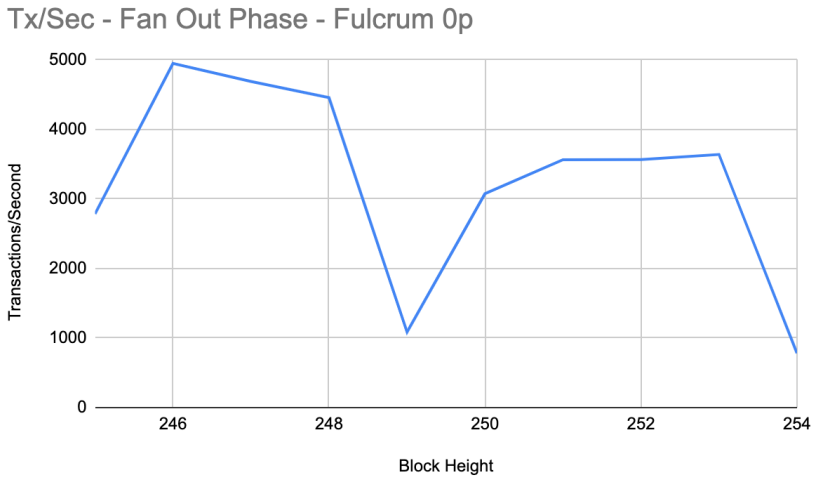
https://github.com/softwareverde/bch-scaling
https://github.com/softwareverde/bch-scaling-bchn
https://github.com/cculianu/Fulcrum.git

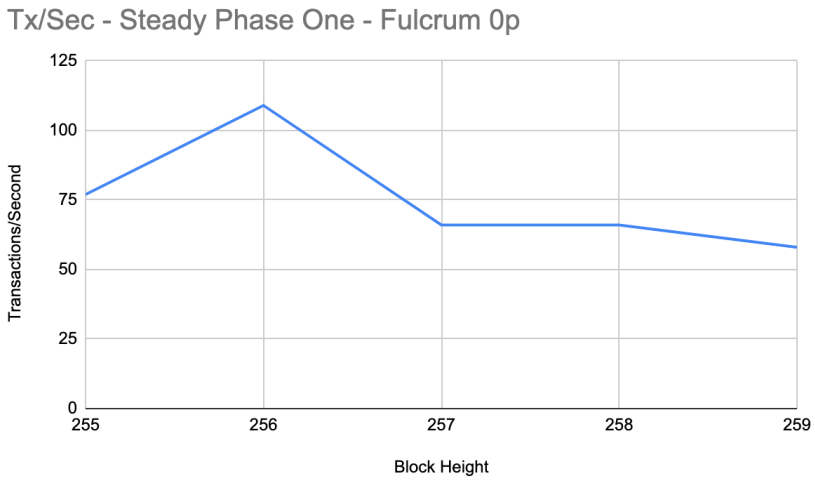
Graphs

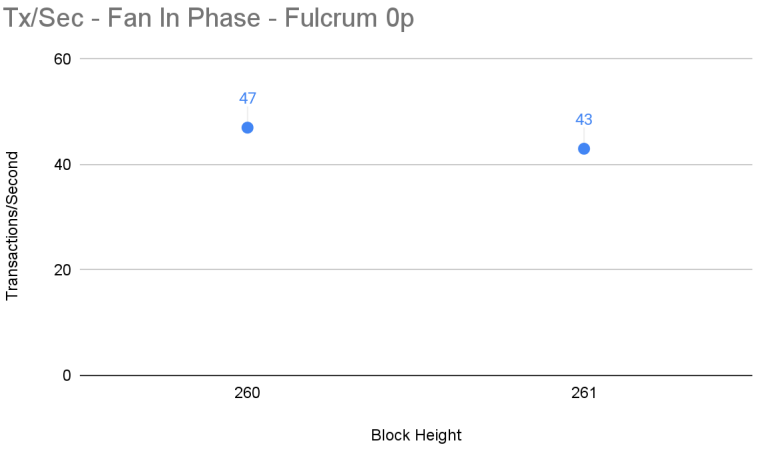

Tx/Sec - Fan Out Phase - BCHN 0p
40000
30000
20000
10000
0
Transactions/Second
246
248
250
252
254
Block Height

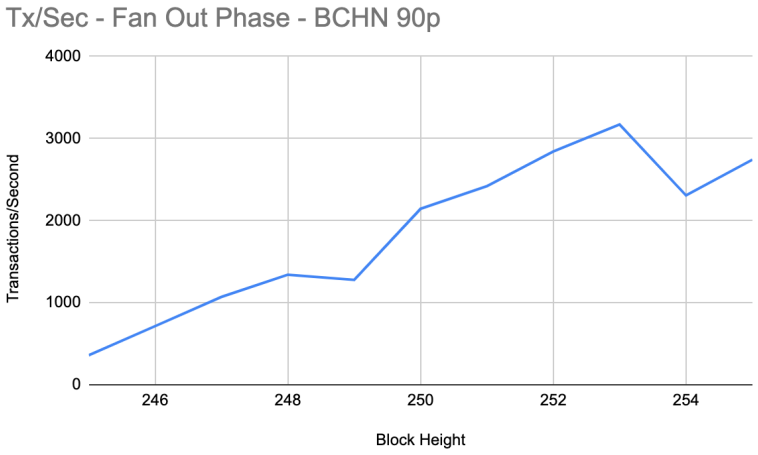

Tx/Sec - Steady State One - BCHN 0p
40000
30000
20000
10000
0
255
256
257
258
259

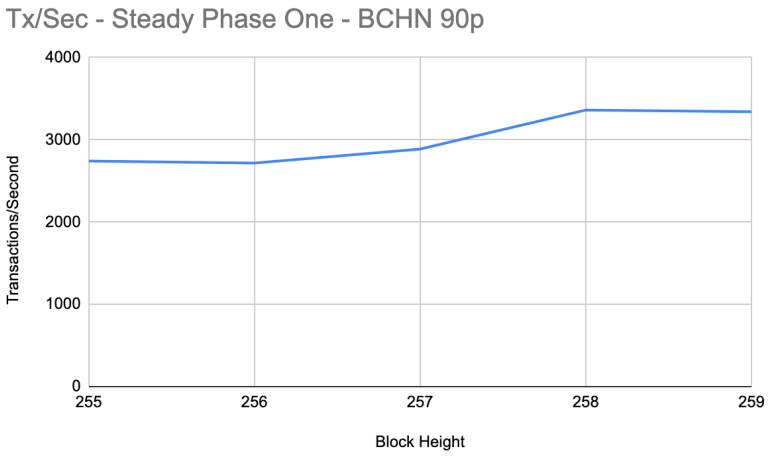

Tx/Sec - Fan In Phase - BCHN 0p
600000
400000
200000
0
260
261

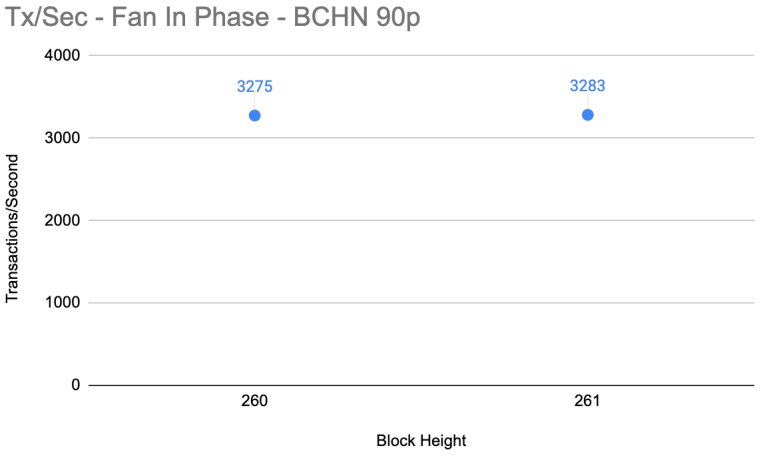

Tx/Sec - Fan Out Phase - Fulcrum 0p
5000
4000
3000
2000
1000
0
Transactions/Second
246
248
250
252
254
Block Height


Tx/Sec - Steady Phase One - Fulcrum 0p
125
100
75
50
25
0
Transactions/Second
255
256
257
258
259
Block Height

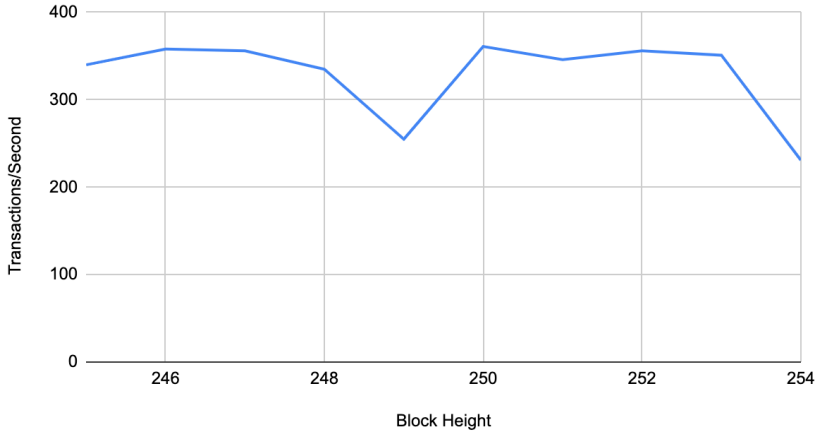

Tx/Sec - Fan In Phase - Fulcrum 0p
60
40
20
0
Transactions/Second
47
43
260
261
Block Height


Tx/Sec - Fan Out Phase - BCHN 90p
4000
3000
2000
1000
0
Transactions/Second
246
248
250
252
254
Block Height

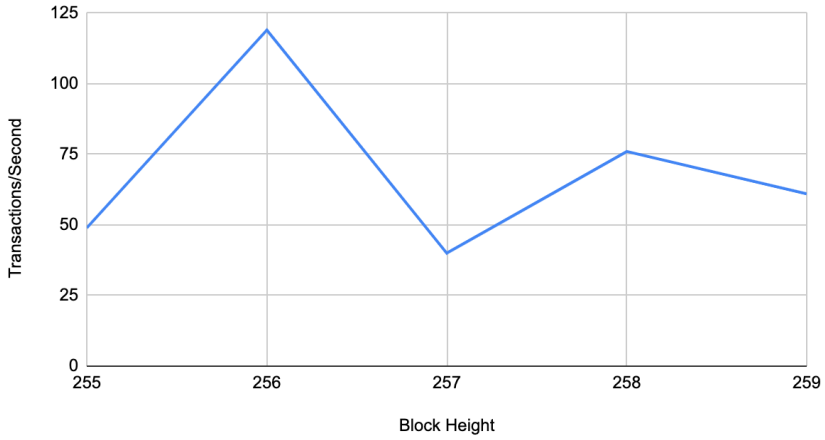

Tx/Sec - Steady Phase One - BCHN 90p
4000
3000
2000
1000
0
Transactions/Second
255
256
257
258
259
Block Height


Tx/Sec - Fan In Phase - BCHN 90p
4000
3000
2000
1000
0
Transactions/Second
3275
3283
260
261
Block Height

Tx/Sec - Fan Out Phase - Fulcrum 90p



Tx/Sec - Steady Phase One - Fulcrum 90p



Tx/Sec - Fan In Phase - Fulcrum 90p