Spartan Gold’s Additional Features

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1. OVERVIEW

In this project, we implement some features available to Bitcoin that are not immediately available to the cryptocurrency Spartan Gold. The purpose of this project is to enhance the functionality of Spartan Gold and make it a bit more robust in the capabilities of the cryptocurrency.

First, we will need to take the time to completely understand the features that we plan to implement that are currently in Bitcoin. We will be taking a look at using Merkle Trees to store transactions, looking at fixed block size, and variable Proof-of-work. After analyzing these functions and features in Bitcoin, we will begin our own adaptation of these features in Spartan Gold.

Once we finish the implementation of these features we will take the time to test that the functions work with Spartan Gold. We will use test methods similar to those practiced in class like when using a fake network, sample clients and miners, and seeing how the functions work with these different variables.

2. OBJECTIVES AND SCOPE

The objectives of this project are:

1. Implement Merkle Trees to Store Transactions
    a. This will hopefully provide a more efficient and secure method of verifying transaction integrity
2. Implement a Fixed Block Size
    a. This will potentially provide more predictable transaction processing times. Although Bitcoin regularly adjusts its time to take 10 minutes, this may help to reduce the risks of network congestion.
3. Implement a Variable Proof-of-Work
    a. We are hoping that this implementation will help to adjust the difficulty of mining based on the network demands.

   b. Ensure that the network can adapt to changes when it comes to transaction volume and maintain security

4. Test
   a. Finally, we will test these features to ensure that they all work together with Spartan Gold

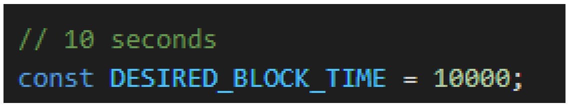
The scope of this project will be limited to the implementation of these features and objectives. This project will involve researching the necessary information, developing the project, and testing all the features. We won't be having any significant changes to the overall infrastructure of Spartan Gold or Bitcoin. We will simply be adding more capabilities to Spartan Gold.

3. IMPLEMENTATION

3.1 Variable Proof-of-Work

Implementing variable proof-of-work is important because we don't want a powerful network to be able to continuously mine blocks at a faster and faster rate. Currently, Spartan Gold has a static target that miners will need to hit to successfully prove that they have mined a block. This means that with a powerful machine, blocks can be mined out rather quickly, this is something we want to change. Currently, Bitcoin has a PoW system that increases or decreases the difficulty of the PoW target to keep the time to produce a block to around ten minutes. So, every ten minutes a miner somewhere is able to produce a block and earn new bitcoin. However, in Spartan Gold, blocks are currently mined out nearly every half a second. So for our purposes, we will try to keep the time to discover blocks to around ten seconds. These are the steps:

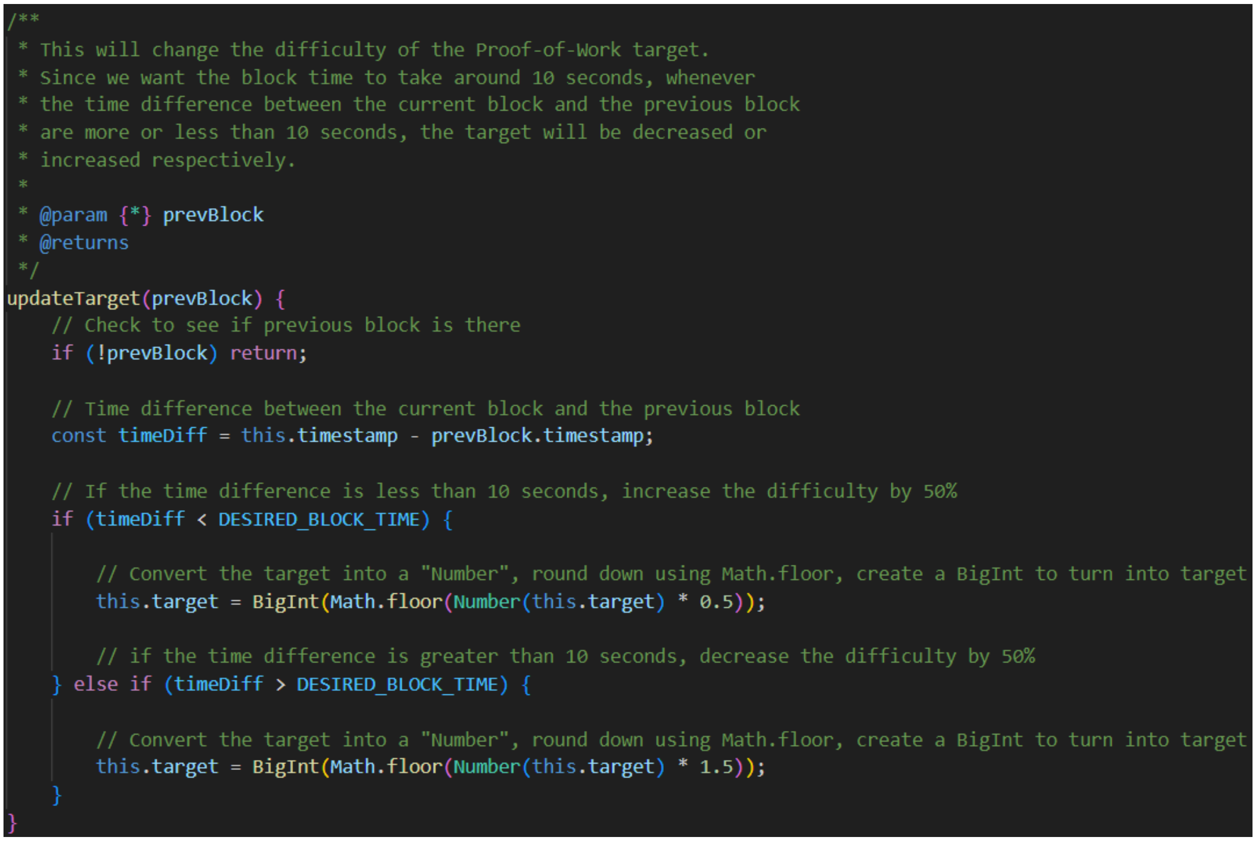
- First, we will do this by creating a constant called DESIRED_BLOCK_TIME and setting it to 10,000 ms which is equivalent to 10 seconds.



```
// 10 seconds
const DESIRED_BLOCK_TIME = 10000;
```

Figure 1: Set value for desired block time in block.js

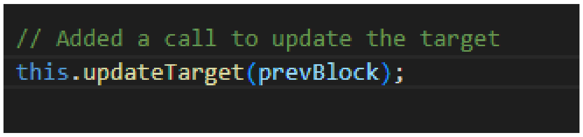
- Secondly, we will create the method updateTarget which will take in the prevBlock as an argument. It will check if the prevBlock is there and continue to get the time difference between the previous block and the current block being created. Once the time difference is calculated it will be measured against the DESIRED_BLOCK_TIME of 10 seconds. If the amount of time is less than 10 seconds, then the difficulty will be increased. If the amount of time is more than 10 seconds then the difficulty will be decreased. The difficulty of the target will be changed by converting the target into a Number, which will then be rounded down by using Math.floor, then turning it into a BigInt which matches the target. It will then either be increased or decreased by 50% to see a change in the amount of time it takes to mine a block.



```
/**
 * This will change the difficulty of the Proof-of-Work target.
 * Since we want the block time to take around 10 seconds, whenever
 * the time difference between the current block and the previous block
 * are more or less than 10 seconds, the target will be decreased or
 * increased respectively.
 *
 * @param {*} prevBlock
 * @returns
 */
updateTarget(prevBlock) {
    // Check to see if previous block is there
    if (!prevBlock) return;

    // Time difference between the current block and the previous block
    const timeDiff = this.timestamp - prevBlock.timestamp;

    // If the time difference is less than 10 seconds, increase the difficulty by 50%
    if (timeDiff < DESIRED_BLOCK_TIME) {

        // Convert the target into a "Number", round down using Math.floor, create a BigInt to turn into target
        this.target = BigInt(Math.floor(Number(this.target) * 0.5));

        // if the time difference is greater than 10 seconds, decrease the difficulty by 50%
    } else if (timeDiff > DESIRED_BLOCK_TIME) {

        // Convert the target into a "Number", round down using Math.floor, create a BigInt to turn into target
        this.target = BigInt(Math.floor(Number(this.target) * 1.5));
    }
}
```

Figure 2: updateTarget method with explanation in block.js

- Thirdly, the updateTarget method is called in the constructor of the block. So whenever a block is being created, the target will be updated based on the time difference, eventually leading to a 10-second block time.



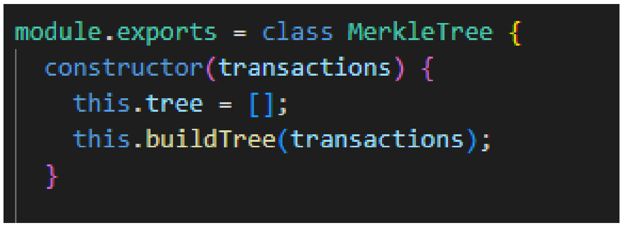
```
// Added a call to update the target
this.updateTarget(prevBlock);
```

Figure 3: Call updateTarget() in constructor of block.js

3.2 Merkle Trees for Storage

Merkle trees are an integral part of a cryptocurrency because they provide many levels of security and integrity for the blockchain that is desired. Currently, Spartan Gold stores the blockchain on seemingly a linked list or map data structure. This gives an opportunity to implement Merkle trees to improve data integrity, security, and efficient ways of verification, and making it harder for people to tamper with the data. These are the steps to do it:

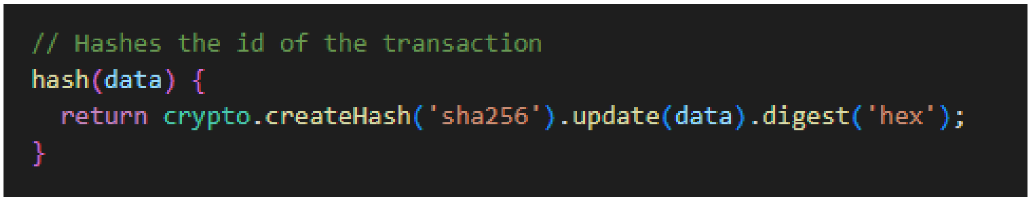
- First, we create a simple implementation of a Merkle Tree. We will create a new class called MerkleTree, in which the constructor takes in a list of transactions to build the tree. It starts by initializing an array called a tree and calling buildTree(transactions) to build the tree.



```
module.exports = class MerkleTree {
  constructor(transactions) {
    this.tree = [];
    this.buildTree(transactions);
  }
```

Figure 4: Export Merkle Tree in merkletree.js

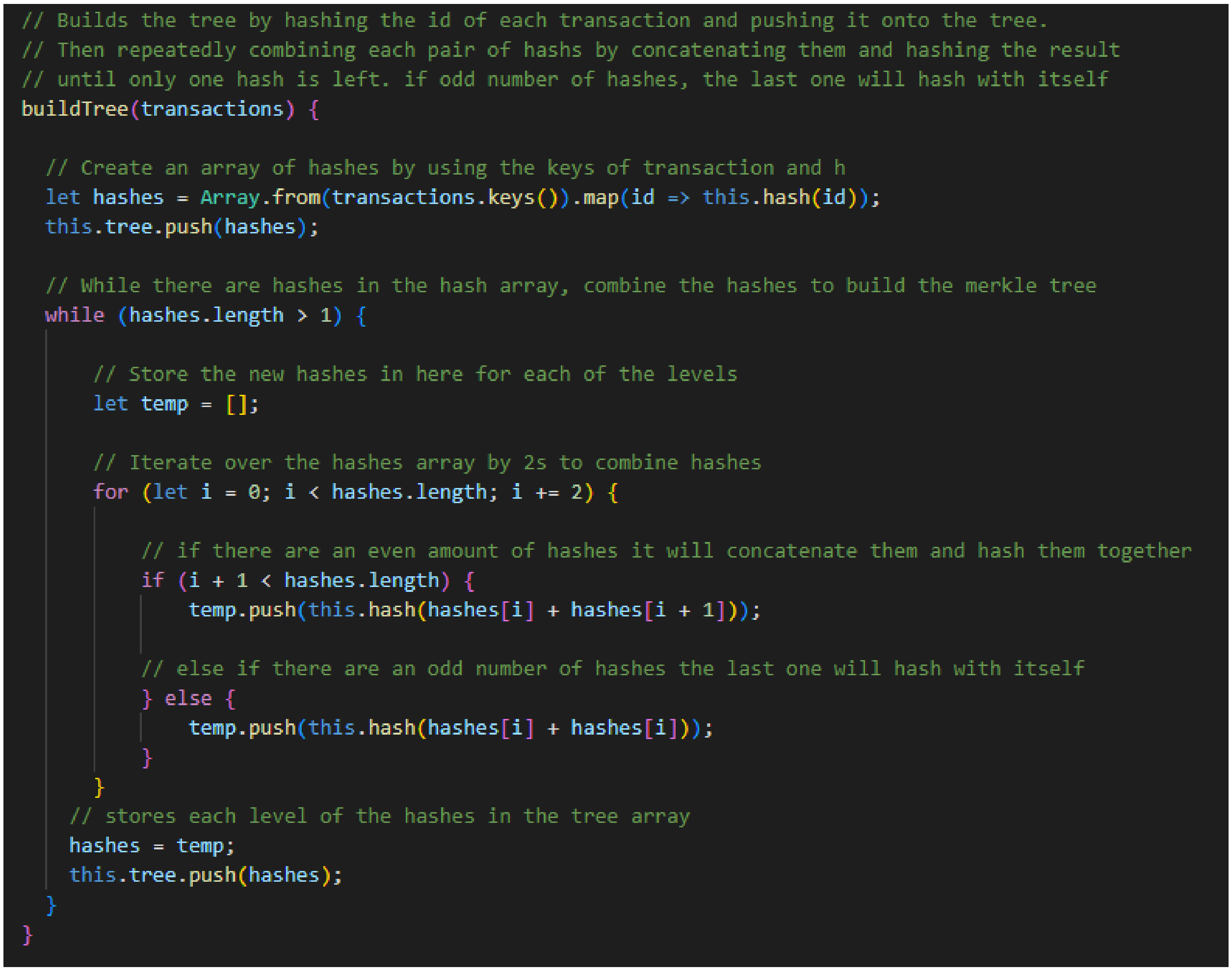
- Second, we create a helper method called hash which will hash the data provided to it, in this case, it will be the id of the transactions.



```
// Hashes the id of the transaction
hash(data) {
  return crypto.createHash('sha256').update(data).digest('hex');
}
```

Figure 5: hash method in merkletree.js

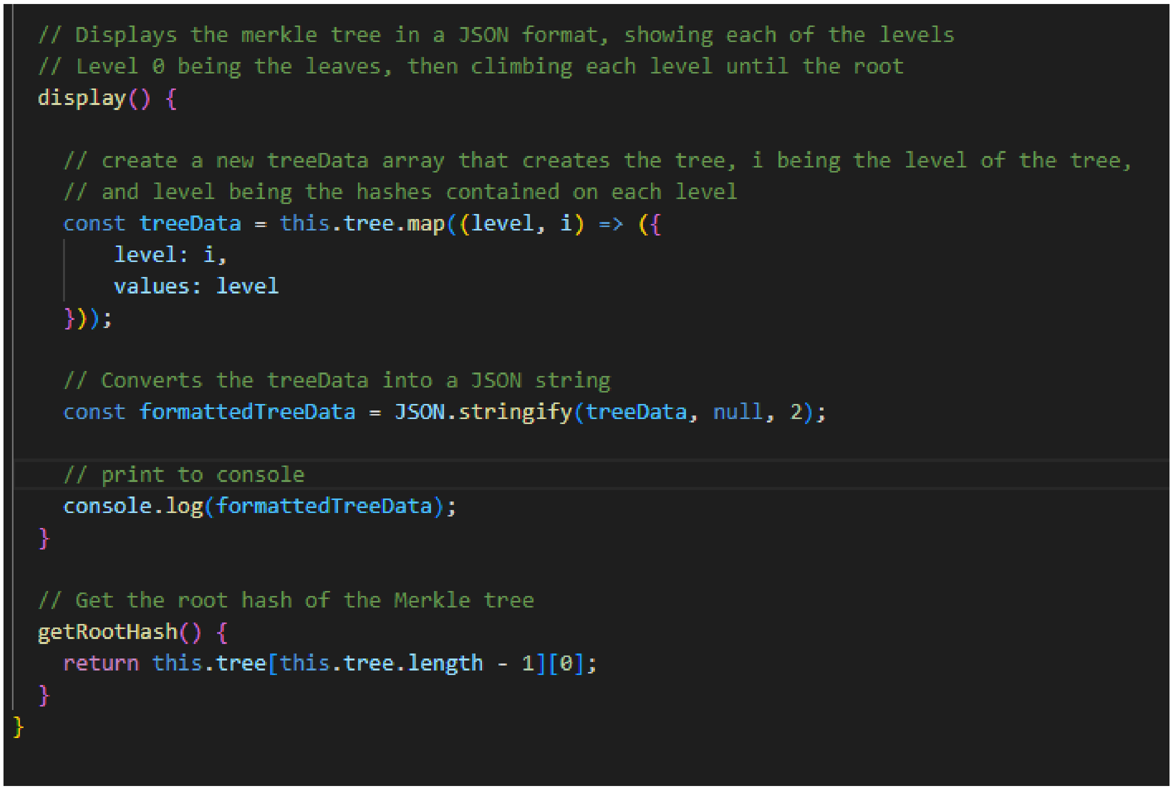
- Third, we implement the buildTree method which takes in a list of transactions to build the tree. It will begin by using the transactions, getting their ids and hashing them, mapping them to each appropriate transaction. Next, we will push the hashes onto the tree array initialized in the constructor. Next, we will build the Merkle Tree by combining two hashes at a time and then hashing them together to form the next level. If there are an even amount of hashes, then each pair will be concatenated and hashed together to form the hash in the next level. If there are an odd number of hashes, the last lonely hash will be hashed with itself. All of these new hashes are stored in a temporary array and pushed to the tree array at the end.



```
// Builds the tree by hashing the id of each transaction and pushing it onto the tree.
// Then repeatedly combining each pair of hashs by concatenating them and hashing the result
// until only one hash is left. if odd number of hashes, the last one will hash with itself
buildTree(transactions) {

  // Create an array of hashes by using the keys of transaction and h
  let hashes = Array.from(transactions.keys()).map(id => this.hash(id));
  this.tree.push(hashes);

  // While there are hashes in the hash array, combine the hashes to build the merkle tree
  while (hashes.length > 1) {

      // Store the new hashes in here for each of the levels
      let temp = [];

      // Iterate over the hashes array by 2s to combine hashes
      for (let i = 0; i < hashes.length; i += 2) {

          // if there are an even amount of hashes it will concatenate them and hash them together
          if (i + 1 < hashes.length) {
              temp.push(this.hash(hashes[i] + hashes[i + 1]));

          // else if there are an odd number of hashes the last one will hash with itself
          } else {
              temp.push(this.hash(hashes[i] + hashes[i]));
          }
      }
    // stores each level of the hashes in the tree array
    hashes = temp;
    this.tree.push(hashes);
  }
}
```

Figure 6: buildTree method with explanation in merkle.js

- Lastly, the display method will display the Merkle Tree after it is built.



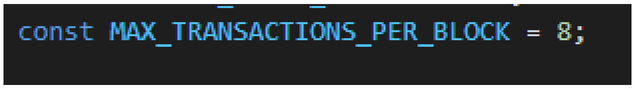
```
  // Displays the merkle tree in a JSON format, showing each of the levels
  // Level 0 being the leaves, then climbing each level until the root
  display() {

    // create a new treeData array that creates the tree, i being the level of the tree,
    // and level being the hashes contained on each level
    const treeData = this.tree.map((level, i) => ({
        level: i,
        values: level
    }));

    // Converts the treeData into a JSON string
    const formattedTreeData = JSON.stringify(treeData, null, 2);

    // print to console
    console.log(formattedTreeData);
  }

  // Get the root hash of the Merkle tree
  getRootHash() {
    return this.tree[this.tree.length - 1][0];
  }
}
```

Figure 7: display method with explanation in merkletree.js

3.3 Fixed Block Size

Fixed block size is important to Bitcoin because it helps to maintain a predictable and consistent block creation time, helps with resource management, and helps with maintaining the decentralized ability of Bitcoin. Currently, Spartan Gold doesn't have a fixed block size, so each block can be a varying amount of size depending on each side of the transaction. The current limit of Bitcoin's block size is limited to 1 MB, however, this can be roughly 2000 transactions, which is very large for our purposes. So we will play with numbers between 0-10 transactions per block. This is how we did it:

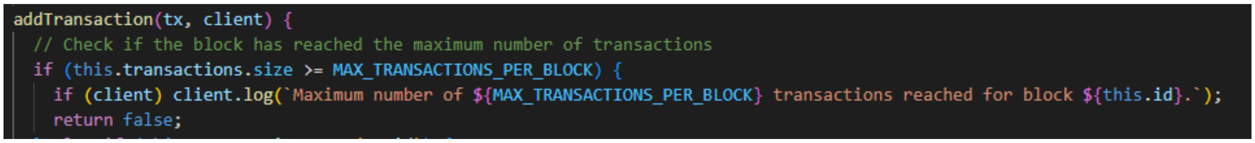
- First, we set a constant MAX_TRANSACTIONS_PER_BLOCK and we are able to set this to whatever limit we want it to be. For this example, we used a limit of 8.



```
const MAX_TRANSACTIONS_PER_BLOCK = 8;
```

Figure 8: Set value for max transaction per block in block.js

- Second, we put a constraint in addTransaction of the block class to check whether the transactions are equal to the MAX_TRANSACTIONS_PER_BLOCK we set. If so, then we return false and stop any more transactions from being added to the block.

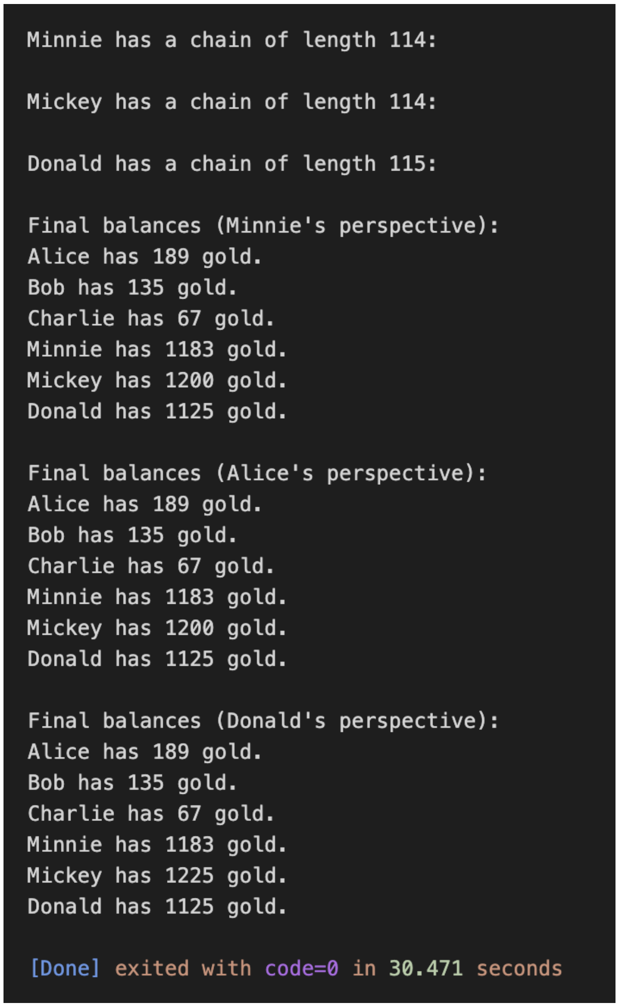


```
addTransaction(tx, client) {
  // Check if the block has reached the maximum number of transactions
  if (this.transactions.size >= MAX_TRANSACTIONS_PER_BLOCK) {
    if (client) client.log(`Maximum number of ${MAX_TRANSACTIONS_PER_BLOCK} transactions reached for block ${this.id}.`);
    return false;
```

Figure 9: The main if statement of addTransaction method in block.js

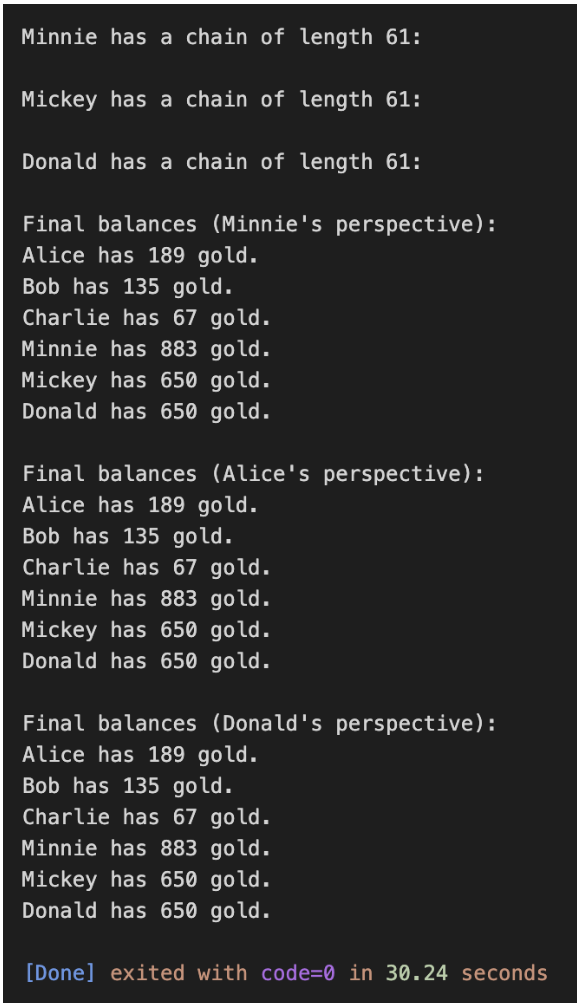
4. RESULTS

4.1 Variable Proof-of-Work



```
Minnie has a chain of length 114:

Mickey has a chain of length 114:

Donald has a chain of length 115:

Final balances (Minnie's perspective):
Alice has 189 gold.
Bob has 135 gold.
Charlie has 67 gold.
Minnie has 1183 gold.
Mickey has 1200 gold.
Donald has 1125 gold.

Final balances (Alice's perspective):
Alice has 189 gold.
Bob has 135 gold.
Charlie has 67 gold.
Minnie has 1183 gold.
Mickey has 1200 gold.
Donald has 1125 gold.

Final balances (Donald's perspective):
Alice has 189 gold.
Bob has 135 gold.
Charlie has 67 gold.
Minnie has 1183 gold.
Mickey has 1225 gold.
Donald has 1125 gold.

[Done] exited with code=0 in 30.471 seconds
```

Figure 10: Without Variable PoW

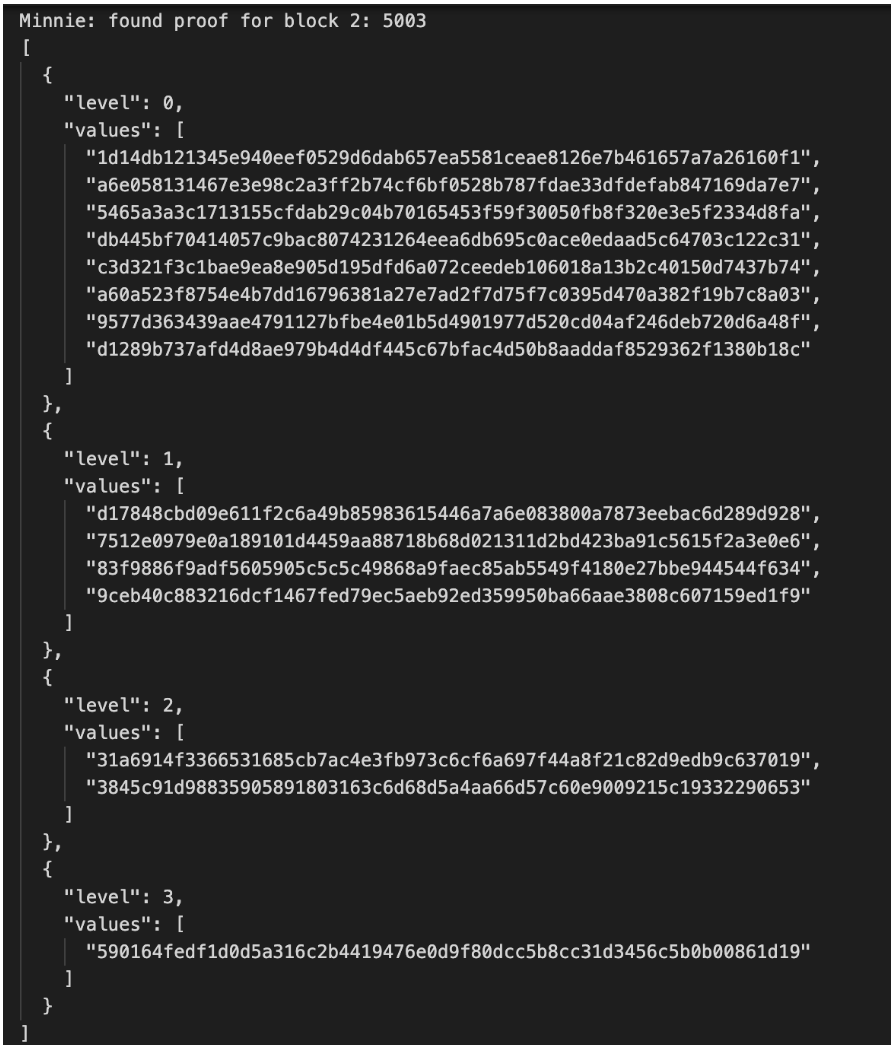


```
Minnie has a chain of length 61:

Mickey has a chain of length 61:

Donald has a chain of length 61:

Final balances (Minnie's perspective):
Alice has 189 gold.
Bob has 135 gold.
Charlie has 67 gold.
Minnie has 883 gold.
Mickey has 650 gold.
Donald has 650 gold.

Final balances (Alice's perspective):
Alice has 189 gold.
Bob has 135 gold.
Charlie has 67 gold.
Minnie has 883 gold.
Mickey has 650 gold.
Donald has 650 gold.

Final balances (Donald's perspective):
Alice has 189 gold.
Bob has 135 gold.
Charlie has 67 gold.
Minnie has 883 gold.
Mickey has 650 gold.
Donald has 650 gold.

[Done] exited with code=0 in 30.24 seconds
```

Figure 11: With Variable PoW

4.2 Merkle Trees for Storage

This shows the different hashes of the transactions and the different levels that the Merkle Tree has. Level 0 is the leaf nodes which hold the 8 transaction hashes, then moving up each level we can see the amount of hashes being cut in half, showing that they are being hashed in pairs to form a new hash up the tree, until there is only 1 Merkle root hash.

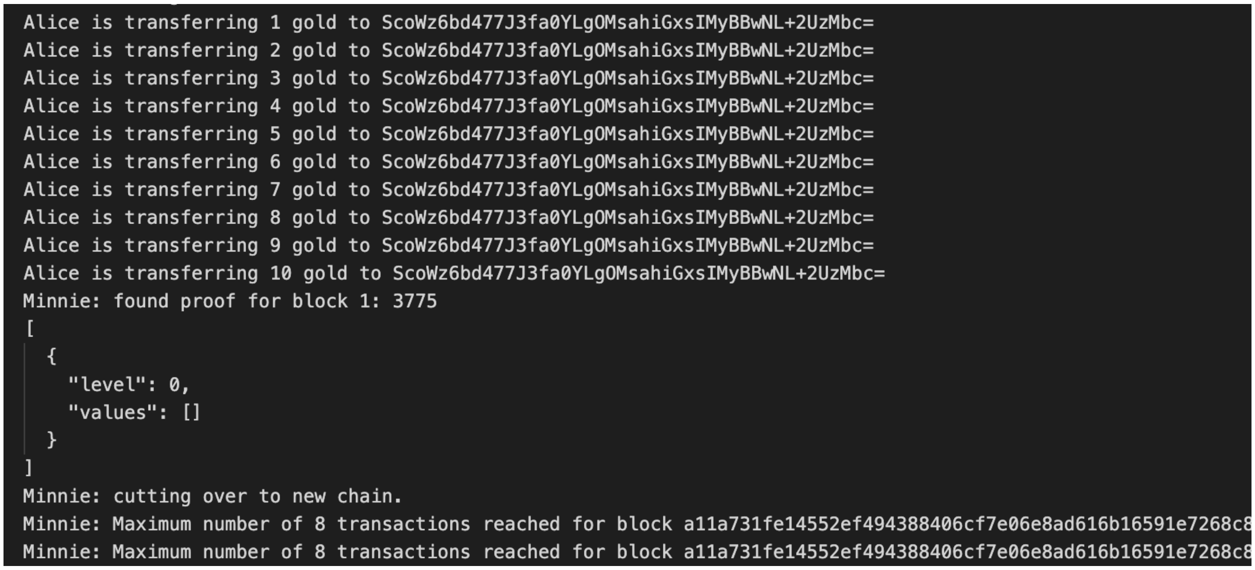


```
Minnie: found proof for block 2: 5003
[
  {
    "level": 0,
    "values": [
      "1d14db121345e940eef0529d6dab657ea5581ceae8126e7b461657a7a26160f1",
      "a6e058131467e3e98c2a3ff2b74cf6bf0528b787fdae33dfdefab847169da7e7",
      "5465a3a3c1713155cfdab29c04b70165453f59f30050fb8f320e3e5f2334d8fa",
      "db445bf70414057c9bac8074231264eea6db695c0ace0edaad5c64703c122c31",
      "c3d321f3c1bae9ea8e905d195dfd6a072ceedeb106018a13b2c40150d7437b74",
      "a60a523f8754e4b7dd16796381a27e7ad2f7d75f7c0395d470a382f19b7c8a03",
      "9577d363439aae4791127bfbe4e01b5d4901977d520cd04af246deb720d6a48f",
      "d1289b737afd4d8ae979b4d4df445c67bfac4d50b8aaddaf8529362f1380b18c"
    ]
  },
  {
    "level": 1,
    "values": [
      "d17848cbd09e611f2c6a49b85983615446a7a6e083800a7873eebac6d289d928",
      "7512e0979e0a189101d4459aa88718b68d021311d2bd423ba91c5615f2a3e0e6",
      "83f9886f9adf5605905c5c5c49868a9faec85ab5549f4180e27bbe944544f634",
      "9ceb40c883216dcf1467fed79ec5aeb92ed359950ba66aae3808c607159ed1f9"
    ]
  },
  {
    "level": 2,
    "values": [
      "31a6914f3366531685cb7ac4e3fb973c6cf6a697f44a8f21c82d9edb9c637019",
      "3845c91d98835905891803163c6d68d5a4aa66d57c60e9009215c19332290653"
    ]
  },
  {
    "level": 3,
    "values": [
      "590164fedf1d0d5a316c2b4419476e0d9f80dcc5b8cc31d3456c5b0b00861d19"
    ]
  }
]
```

Figure 12: Merkle tree levels and values are shown when running driver.js

4.3 Fixed Block Size

In the figure, we can see that Alice makes 10 transactions, but since we limit the block size to only contain 8 transactions, the last 2 are blocked from being added to the block.



```
Alice is transferring 1 gold to ScoWz6bd477J3fa0YLgOMsahiGxsIMyBBwNL+2UzMbc=
Alice is transferring 2 gold to ScoWz6bd477J3fa0YLgOMsahiGxsIMyBBwNL+2UzMbc=
Alice is transferring 3 gold to ScoWz6bd477J3fa0YLgOMsahiGxsIMyBBwNL+2UzMbc=
Alice is transferring 4 gold to ScoWz6bd477J3fa0YLgOMsahiGxsIMyBBwNL+2UzMbc=
Alice is transferring 5 gold to ScoWz6bd477J3fa0YLgOMsahiGxsIMyBBwNL+2UzMbc=
Alice is transferring 6 gold to ScoWz6bd477J3fa0YLgOMsahiGxsIMyBBwNL+2UzMbc=
Alice is transferring 7 gold to ScoWz6bd477J3fa0YLgOMsahiGxsIMyBBwNL+2UzMbc=
Alice is transferring 8 gold to ScoWz6bd477J3fa0YLgOMsahiGxsIMyBBwNL+2UzMbc=
Alice is transferring 9 gold to ScoWz6bd477J3fa0YLgOMsahiGxsIMyBBwNL+2UzMbc=
Alice is transferring 10 gold to ScoWz6bd477J3fa0YLgOMsahiGxsIMyBBwNL+2UzMbc=
Minnie: found proof for block 1: 3775
[
  {
    "level": 0,
    "values": []
  }
]
Minnie: cutting over to new chain.
Minnie: Maximum number of 8 transactions reached for block a11a731fe14552ef494388406cf7e06e8ad616b16591e7268c8
Minnie: Maximum number of 8 transactions reached for block a11a731fe14552ef494388406cf7e06e8ad616b16591e7268c8
```

Figure 13: Maximum number of transactions reached for the specified block

5. CHALLENGES

Implementing different Bitcoin features with Spartan Gold can be a challenging, but rewarding endeavor. The first challenge we had to overcome was implementing a variable Proof-of-Work. This was initially pretty difficult because we had to figure out how to measure the difference in time between blocks. Navigating the different fields that a block had, figuring out how the target was initially set, how to manipulate the target to make it easier or harder, and how to implement it.

The next major challenge that was presented to us was implementing the Merkle Trees. We had a previous lab on Merkle Trees, so the understanding of how the Merkle Tree worked was already there, so we initially thought this wouldn't be too much trouble. However, the Merkle Trees became the most challenging aspect of this project. Using the previous lab Merkle Tree and integrating it into Spartan Gold became more difficult than simply starting from scratch and creating a separate implementation of the Merkle Tree. However, in time we were able to write a MerkleTree class that could build the tree using a list of transactions and display it.

Setting the fixed block size was actually the least challenging because we used transactions as a way to limit the size of each block. However, trying to limit the size of the block based on the actual amount of memory size like Bitcoin's 1 MB block size, would have been much more challenging.

6. CONCLUSION

The project we undertook provided us with invaluable insights into the Proof-of-Work mechanism and the way it functions within the context of Bitcoin mining. The practical application of this system allowed us to fully understand the extent of its variability and the impact it has on the rate of mining.

Moreover, our work on Merkle Trees enabled us to develop a much more comprehensive understanding of their builds and structures. We were able to delve deeper into the intricacies of these trees and identify the most efficient ways of constructing and organizing them.

Additionally, we also gained a greater awareness of the importance of limiting the size of a block. By exploring different methods of doing this, we discovered ways to optimize block size while still maintaining the integrity of the blockchain.

Overall, this project has been an immensely valuable learning experience for us. Through hands-on experimentation and exploration, we have gained a deeper understanding of the complex systems that underpin cryptocurrencies like Bitcoin, and we are better equipped to tackle the challenges and opportunities that arise within this dynamic and rapidly evolving field.

7. FUTURE WORK

Implementing these features into Spartan Gold was a challenging, but rewarding experience. In the future, we would love to implement more features or optimize the current features that we implemented. Our implementation of the Merkle Tree is pretty simple, in which it only builds and displays the Merkle Tree. It doesn't have verification processes, which is a major portion of Merkle Trees.

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