CS1699: Blockchain Technology and Cryptocurrency

14. Variations on a Theme: Non-SHA256 Puzzles

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Recall: Hash Puzzle Properties

1. Difficult to compute
2. Parameterizable (i.e. adjustable) cost
3. Trivial to verify
4. Progress-free (memoryless process)

Bitcoin's Puzzle

- *Partial hash-preimage puzzle*
- Goal is to find block / nonce where:

  $H(block \mid\mid nonce) < target$

- Could we modify this in any way while maintaining the three properties of a good puzzle: Difficult to compute, parameterizable cost, trivial to verify?

Slight Variations on Bitcoin's Puzzle

- Number of 0's or 1's in binary representation of hash
- *H(block || nonce) > target*
- *H(block || nonce) XOR value < target*

What About More Extreme Variations?

- Of course!
- But why would we want to do it?

Mining

- Most Bitcoin users do not mine, as you need specialized hardware
- Is this a good or a bad thing?

ASIC Resistance

- "Disincentivize the use of custom-built hardware for mining"
- This will never be perfect - some hardware will always be better at mining than others (e.g. different instructions on different chipsets)
- Thus, there is always some incentive (assuming a currency with value) to make our own specialized hardware
- But can we *narrow the gap*?

Memory-Hard vs Memory-Bound

- A puzzle that requires lots of memory instead of (or in addition to) lots of CPU power is *memory-hard*
- If time to access memory is limiting factor of computation, the puzzle is *memory-bound*
- *Puzzles can be either, neither or both!*

ASIC Resistance And Memory

- For ASIC resistance, we want puzzles to be both memory-hard and memory-bound… why?
  - Time bound by memory storage, not processor design
    - Variation in memory access relatively small across systems and harder to speed up
    - Harder to parallelize without just buying more memory
- SHA-256 is neither memory-hard nor memory-bound

scrypt

- Pronounced “ess-crypt”, not “script”
- Originally designed for hashing passwords
- Similar to Bitcoin’s partial hash-preimage puzzle but has reliance on

“Simple scrypt” Pseudocode

```
def scrypt(size, seed) {
  buf = [0] * size
  buf[0] = seed
  for j = (1..size) {
    buf[j] = SHA256(V[j -1])
  }
  x = SHA256(buf[size - 1])
  for j = (1..size) {
    k = x % size
    x = SHA256(X ^ buf[k])
  }
  return x
}
```

Simple scrypt

Work out on board

Why Is This Memory-Hard?

- Re-computing all of the values in buffer is possible
- But value of k changes pseudorandomly, thus would need to calculate (on average) *size* / *2* SHA-256 hashes
- If buffer used: *2 * size* computations (O(n))
- No buffer: *size * (size / 2)* computations ($O(n^2)$)

Time/Memory Trade-Offs of scrypt

- Assume buffer of size *size* / 2 (half of original)
- Store values of *buf[k]* iff *k* is even, recalculate later if odd
- Can generalize, can store every kth row of buffer
- Uses *size* / *k* memory, computing *((k + 3)*size)* / 2 iterations of SHA256

“Tipping the Scales” Towards Memory

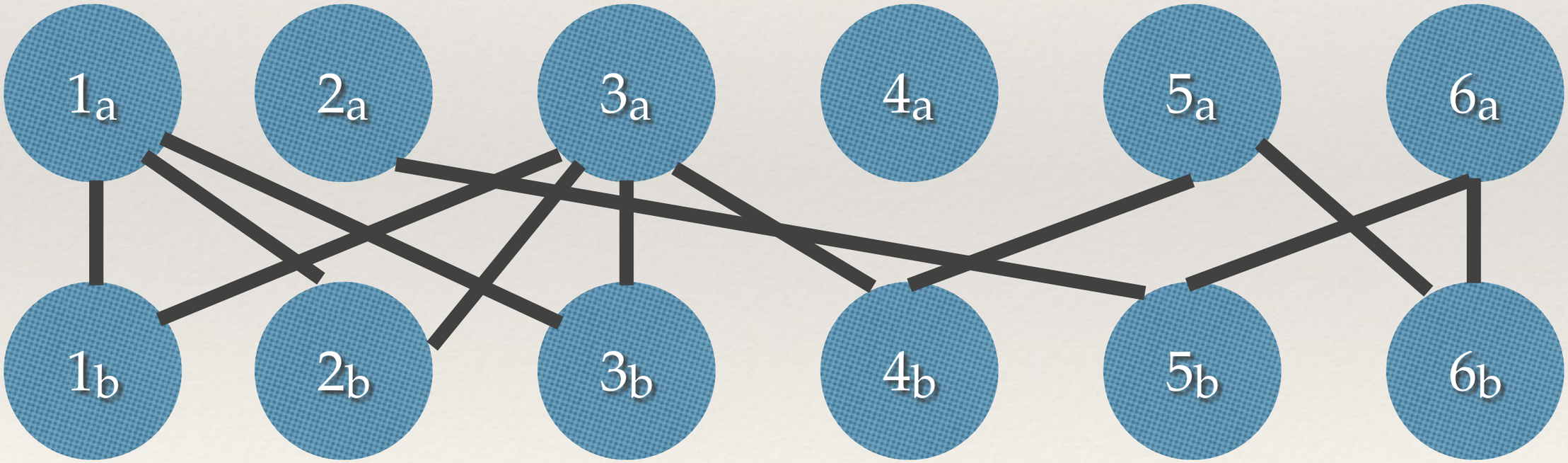
- What if the buffer itself were updated by each iteration?
- Would make time/memory trade-off even more in favor of memory as it would involve lots of recalculation

Cuckoo Cycle

- Graph-theoretic hashing algorithm
- Used for æternity blockchain proof of work
- A variant (Cuckatoo cycle) used in Grin
- https://github.com/tromp/cuckoo
- https://github.com/tromp/cuckoo/blob/master/doc/cuckoo.pdf

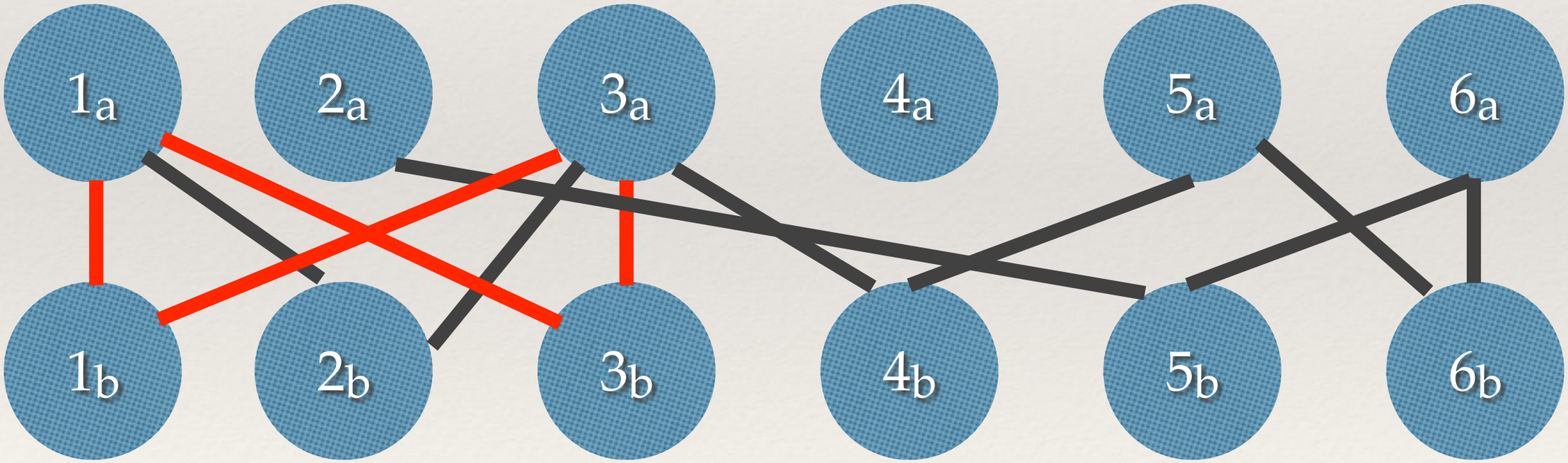
Cuckoo Cycle In A Nutshell

Given a bipartite graph, find a cycle



Cuckoo Cycle In A Nutshell

Given a bipartite graph, find a cycle:
1a - 1b - 3a - 3b - 1a



Using Cuckoo Cycles for PoW

- Given some data, send it through a hash function (Grin and æternity use SIPHASH) multiple times
- Interpret output from hash function as edges between nodes
- Look for cycle of a specific length (for Grin, 42)

Cuckoo Cycle

Work out on board

Is The Cuckoo Cycle A Good Puzzle?

1. *Difficult to compute?* **yes, especially as size number of nodes increase**
2. *Parameterizable (i.e. adjustable) cost?* **yes, increase number of nodes, size of cycle, or add restrictions to which edges are "valid"**
3. *Trivial to verify?* **yes, easy to check if given cycle path**
4. *Progress-free (memoryless process)?* **yes, need to just try different possibilities**