Alternative Mining Puzzles

- Essential Puzzle Requirements
- ASIC-Resistant Puzzles
- Proof-of-Useful-Work
- Non-outsourceable Puzzles
- Proof-of-Stake "Virtual Mining"

Puzzles (recap)

Incentive system steers participants

Basic features of Bitcoin's puzzle

The puzzle is difficult to solve, so attacks are costly

… but not too hard, so honest miners are compensated

Q: What other features could a puzzle have?

On today's menu . . .

Alternative puzzle designs

Used in practice, and speculative

Variety of possible goals

ASIC resistance, pool resistance, intrinsic benefits, etc.

Essential security requirements

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Puzzle Requirements

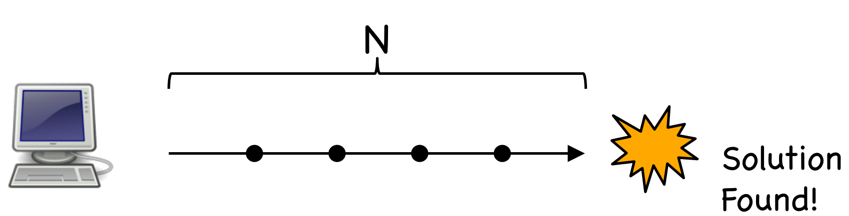
A puzzle should ...

- be cheap to verify
- have adjustable difficulty
- <other requirements>

- have a chance of winning that is proportional to hashpower
  - Large player get only proportional advantage
  - Even small players get proportional compensation

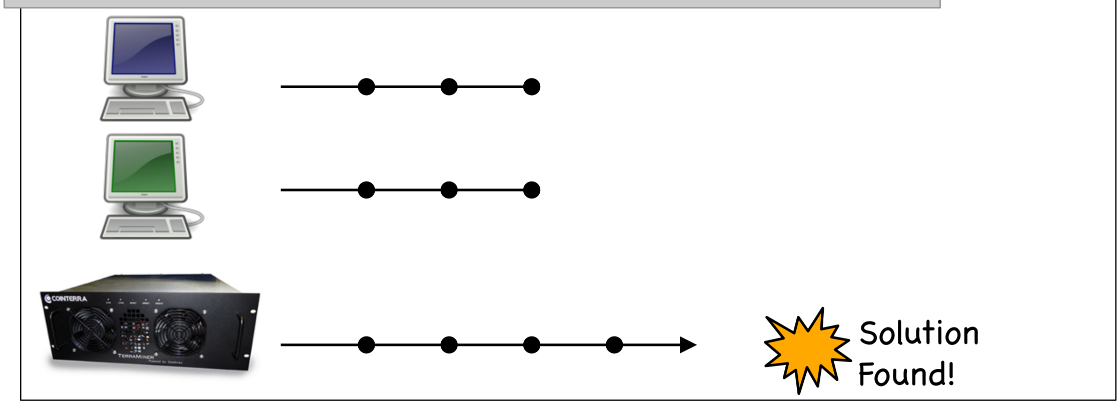
Bad Puzzle: a sequential Puzzle

Consider a puzzle that takes N steps to solve
a "Sequential" Proof of Work

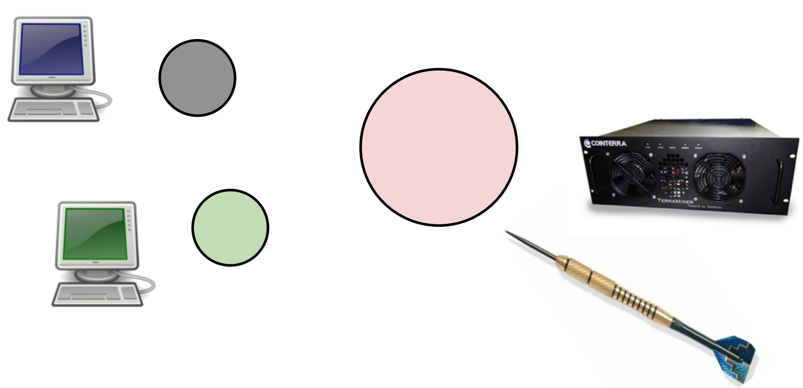


Bad Puzzle: a sequential Puzzle

Problem: fastest miner always wins the race!



Good Puzzle => Weighted Sample



This property is sometimes called progress free.

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ASIC Resistance – Why?!

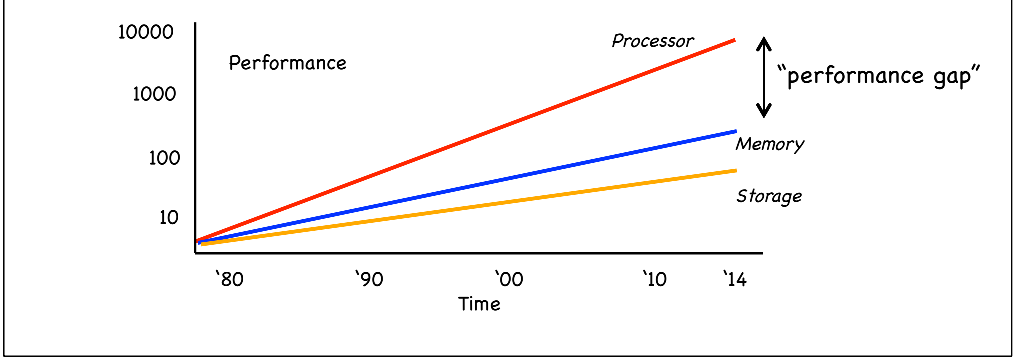
Goal: Ordinary people with idle laptops, PCs, or even mobile phones can mine!

Lower barrier to entry!

Approach: Reduce the gap between custom hardware and general purpose equipment.

Memory-hard Puzzles

Premise: the cost and performance of memory is more stable than for processors



Example: scrypt (Colin Percival, 2009)

Memory hard hash function (requires large amounts of memory)
=> Prevents large-scale parallel attack with limited resources.

Most widely used alternative Bitcoin puzzle (e.g. in LiteCoin)

Also used elsewhere in security (PW-hashing, Tarsnap)

1. Fill memory with random values
2. Read from the memory in random order

scrypt – Step 1 of 2 (write)

Input: **X**

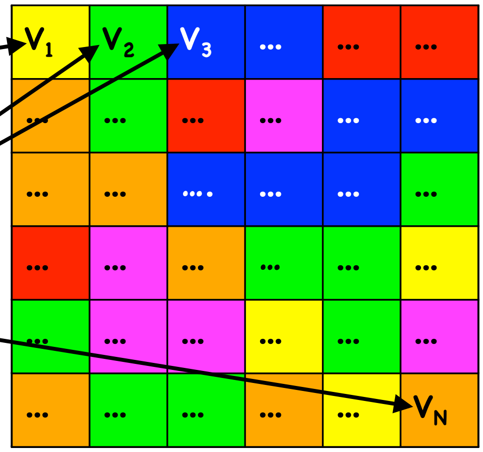
$V_1 = H(X)$

$V_2 = H(V_1) = H(H(X))$

$V_3 = H(V_2) = H^3(X)$

…

$V_N = H^N(X)$



scrypt – Step 2 of 2 (read)

Input: **X**

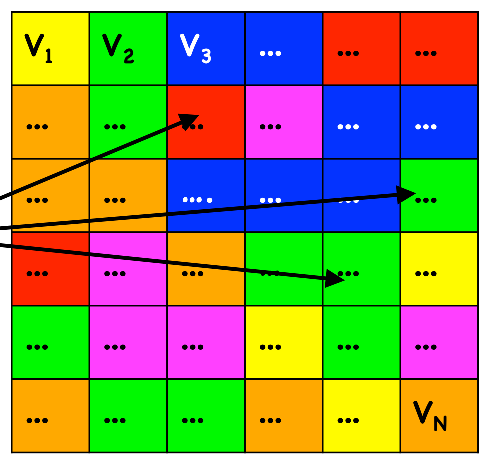
$A := H^{N+1}(X)$

For N iterations:

  $i := A \bmod N$

  $A := H(A \text{ xor } V_i)$

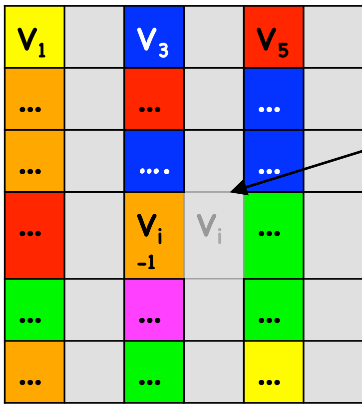
Output: A



scrypt – Time/Memory Tradeoff

Q: Why is this memory-hard?

Reduce memory by half, 1.5x the # steps



Need to access V_i where i is even?

first, access V_{i-1}

then, compute $V_i = H(V_{i-1})$

scrypt - Discussion

Disadvantages:

Also requires *N* steps, *N* memory to check

Is it actually ASIC resistant?

scrypt ASICs are already available!

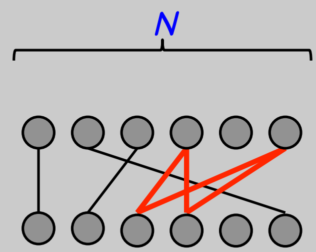
http://zeusminer.com/

Cookoo Hash Cycles (John Tromp, 2014)

Example of a memory hard puzzle that's cheap to verify.

Input: X

```
For i = 1 to E:
   a := H0(X + i)
   b := N + H1(X + i)
   edge(a mod N, b mod N)
```



Is there a cycle of size K? If so, Output: X, K edges

Even more Approaches

More complicated hash functions

X11: 11 different hash functions combined

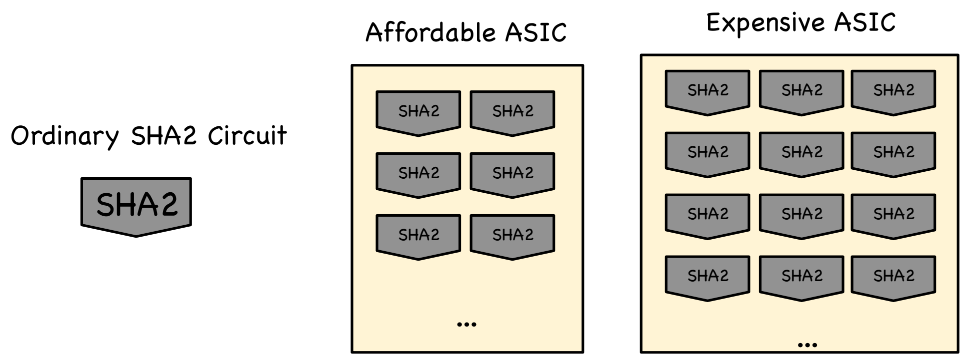
Moving target

Change the puzzle periodically

Counter Argument: SHA2 is fine!

Bitcoin Mining ASICs aren't changing much.

Big ASICs only marginally more performant than small ones.



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Recovering wasted Work

Recall:

between 150 MW – 900 MW power consumed (as of mid 2014)

Natural Question:

Can we recycle this and do something useful?

Candidates – Needle in a Haystack

Natural choices:

- Protein folding (find a low-energy configuration)
- Search for aliens (find anomalous region of signal)

(These have been successful @Home problems)

Challenges:

- Randomly chosen instances must be hard

Primecoin (Sunny King, 2013)

Puzzle based on finding large prime numbers.

Cunningham chain:

$p_1, p_2, \ldots, p_n$ where $p_{i+1} = 2p_i - 1$

each p_i is large (probable) prime

p_1 is divisible by H(prev || mrkl_root || nonce)

Primecoin

Many of the largest known Cunningham chains have come from Primecoin miners.

Q: Is this a hard problem?

Q: Is this useful?

Recovering wasted Hardware

Estimate: More than $100M spent on customized Bitcoin mining hardware!

This hardware investment is otherwise useless.

Idea: How about a puzzle where hardware investment is useful, even if the work is wasted?

Permacoin – Mining with Storage (Miller et al., 2014)

Bitcoin

Permacoin

Side effect:
Massively distributed, replicated storage system

Permacoin

Assume we have a large file F to store

For simplicity: F is chosen globally, at the beginning, by a trusted dealer

Each user stores a random subset of the file

Storage-based Puzzle

1. Build a Merkle tree, where each leaf is a segment of the file

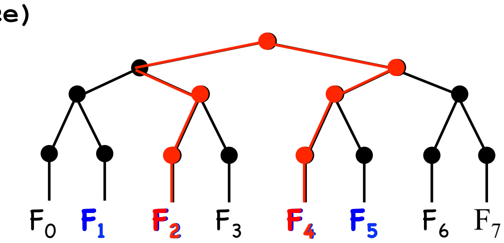
2. Generate a public signing key p_k, which determines a random subset of file segments

F_1 F_2 F_4 F_5

3. Each mining attempt:

F_2 F_4

```
a) Select a random nonce
b) h1 := H(prev || mrkl_root || PK || nonce)
c) h1 selects k segments from subset
d) h2 :=
H(prev || mrkl_root || PK || nonce || F)
e) Winner if  h2 < TARGET
```



Proof-of-Storage to Reduce "Honesty" Cost

"Honest" miners validate every transaction

Validation requires the UTXO database ~200MB

Maintaining the UTXO database doesn't pay

Idea: use Permacoin to reward UTXO storage

Summary

Useful proof-of-work is a natural goal
(while maintaining security requirements)

The benefit must be a pure public good

Viable approaches include storage, prime-finding, others may be possible

Realized benefit so far has been limited

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Large Mining Pools are a Threat

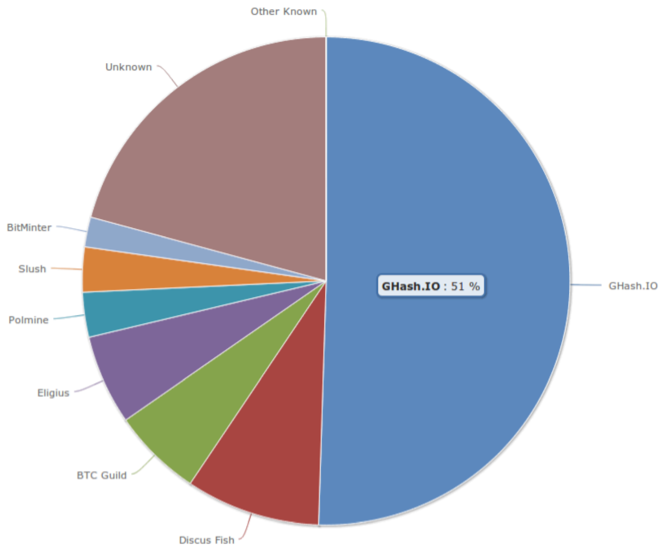
Premise: Bitcoin's core value is decentralization

If power is consolidated in a few large pools, the operators are targets for coercion/hacking

Position: Large pools should be discouraged!

Analogy to voting: It's illegal (in US) to sell your vote

Large Mining Pools are a Threat



June 12, 2014

GHash.IO large mining pool crisis

Large Mining Pools are a Threat

Hacking, Distributed

It's Time For a Hard Bitcoin Fork

Ittay Eyal, and Emin Gün Sirer Friday June 13, 2014 at 02:05 PM

A Bitcoin mining pool, called GHash and operated by an anonymous entity called CEX.io, just reached 51% of total network mining power today. Bitcoin is no longer decentralized. GHash can control Bitcoin transactions.

Is This Really Armageddon?

Yes, it is. GHash is in a position to exercise complete control over which

Large Pools have interesting Dynamics

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Bitcoin Miners Ditch Ghash.io Pool Over Fears of 51% Attack

Published by on January 9, 2014 | Comments Off on Bitcoin Miners Ditch Ghash.io Pool Over Fears of 51% Attack

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Bitcoin miners around the world are starting to leave the Ghash.io bitcoin pool following a significant increase in the pool's hash share.

According to Blockchain.info, Ghash.io accounted for more than 42% of bitcoin mining power a day ago, but over the past 24 hours its share has dropped to 38%.

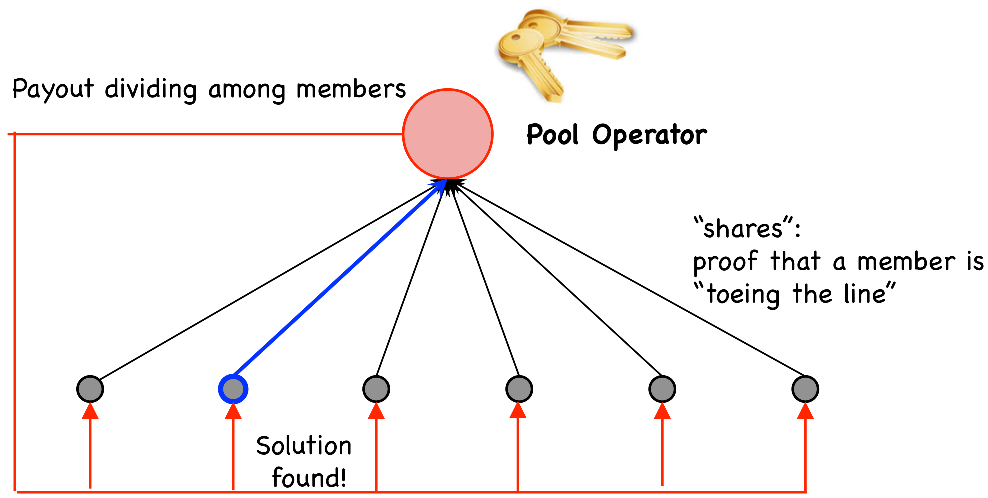
The fact that a single pool has such a high share has prompted some bitcoin miners to voice their concerns on social media and the mining community is starting to take notice. If a single entity ends up controlling more than 50% of the network's computing power, it could – theoretically – wreak havoc on the whole network.

Mining Pools

Observation:
Pool participants don't trust each other.

Pools only work because the "shares" protocol lets members ***prove*** cooperation.

Standard Bitcoin Mining Pool



The Vigilante Attack

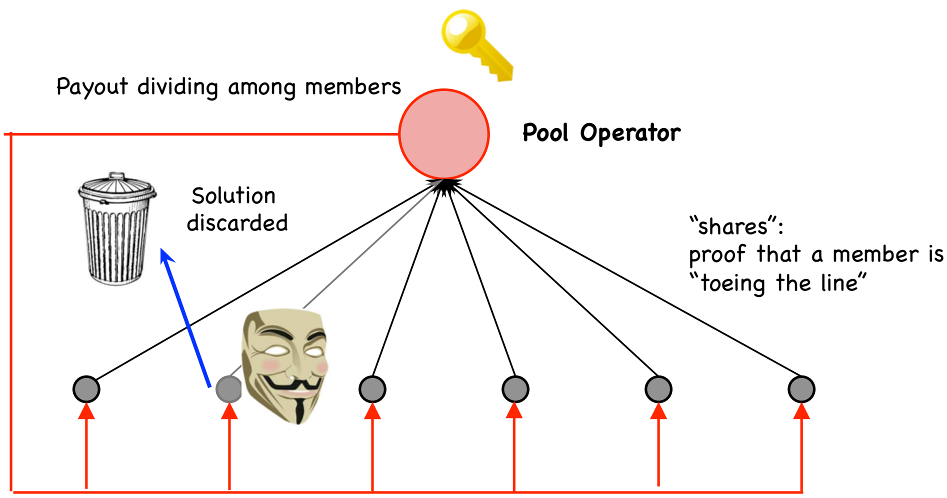
Suppose a Vigilante is angry with a large pool

He submits "shares" like normal....

... but if he finds a real solution, discards it

Pool output is reduced, Vigilante loses a little

The Vigilante Attack

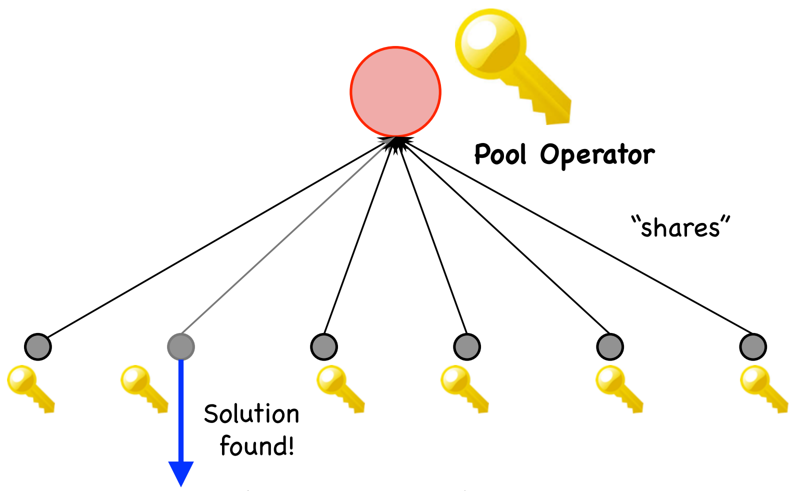


Encouraging the Vigilante (Rewarding Sabotage)

Whoever **FINDS** a solution spends the reward.

Approach:
- searching for a solution requires **SIGNING**, not just hashing. (Knowledge of a private key)
- Private key can be used to spend the reward

Encouraging the Vigilante (Rewarding Sabotage)



Take the money and run!
Also: evade detection

Nonoutsorceable Puzzle

Signature needed to find solution

Public Key

Solution:

`(prev, mrkl_root, nonce, PK, s1, s2)`

Second signature spends reward

such that:

```
H(prev || PK || nonce || s1) < TARGET
VerifySig(PK, s1, prev || nonce)
VerifySig(PK, s2, prev || mrkl_root)
```

Non-outsorceable Puzzles: Concerns

This puzzle discourages all pools
including harmless decentralized P2Pools

Other forms of outsourcing?
might drive pool members to hosted mining

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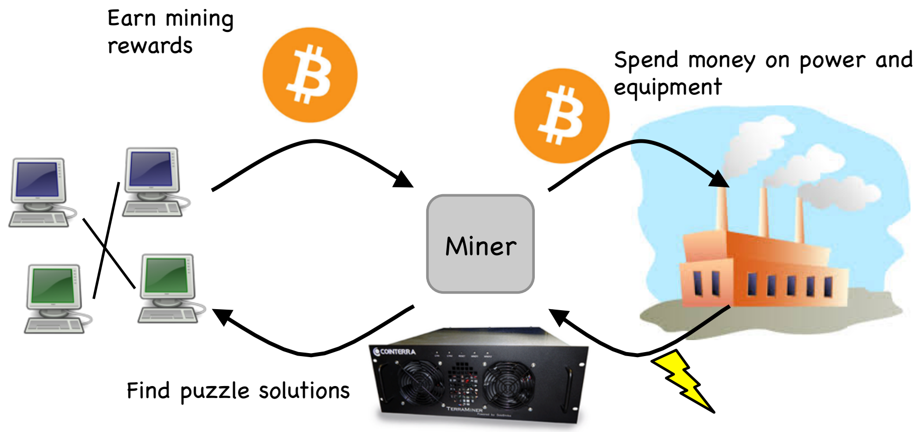
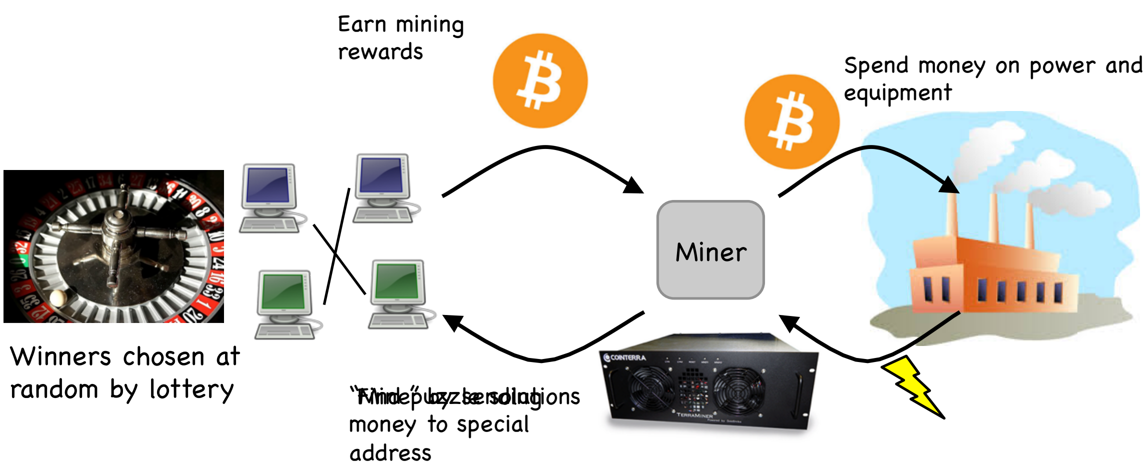
Mining has an unnecessary Step

Proof-of-Work Mining:



Eliminating the unnecessary Step

Virtual Mining:



Benefits of Virtual Mining

Lower overall costs

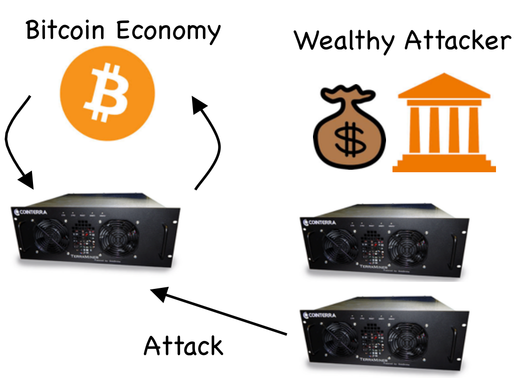
- No harm to the environment
- Savings distributed to all coin holders

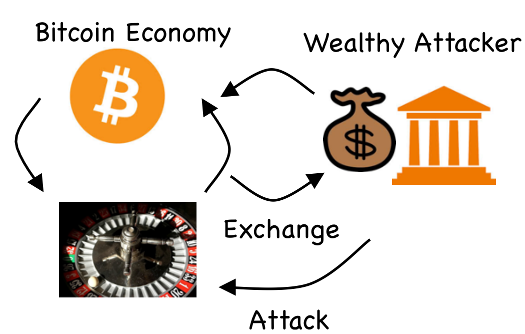
Stakeholder incentives - good stewards?

No ASIC advantage

51% Attack Prevention

- The Bitcoin economy is smaller than the world
- Wealth outside Bitcoin has to move inside





Variations of Virtual Mining

Proof-of-Stake: "Stake" of a coin grows over time as long as the coin is unused

Proof-of-Burn: mining with a coin destroys it

Proof-of-Deposit: can reclaim a coin after some time

Proof-of-Activity: any coin might be win (if online)

Open Questions with Virtual Mining

Q: Is there any security that can only be gained by consuming "real" resources?

YES: Then "waste" is the cost of security

No: Then Proof-of-Work mining may go extinct

Conclusion

Many possible design goals for alternative puzzles:

- Prevent ASIC miners from dominating
- Prevent large pools from dominating
- Intrinsic usefulness
- Eliminate the need for mining hardware at all

Best tradeoff is unclear for now

Outlook: alternatives will coexist for the near future