Decentralization

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Decentralization in Bitcoin

1. Who maintains the ledger?
2. Who has authority over which transactions are valid?
3. Who creates new bitcoins?
4. Who determines how the rules of the system change?
5. How do bitcoins acquire exchange value?
Decentralization in Bitcoin

**Peer-to-peer:**
Open to anyone, low barrier to entry.

**Mining:**
Open to anyone, but inevitable concentration of power often seen as undesirable.

**Updates to software:**
Core developers trusted by community, have great power.
Distributed Consensus

The protocol terminates and all correct nodes decide on the same value. This value must have been proposed by some correct node.
How consensus *could* work in Bitcoin

At any given time:

- All nodes have a sequence of blocks of transactions they have reached consensus on.
- Each node has a set of outstanding transactions it has heard about.
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Consensus is hard

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- Nodes may be malicious.
- Network is imperfect:
  - Not all pairs of nodes connected.
  - Faults in network.
  - Latency.
Bitcoin consensus works better in practice than in theory.
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But theory is important, can help predict unforeseen attacks.
Bitcoin Consensus

*Introduces incentives*

- Possible because it is a currency!
Introduces incentives
- Possible because it is a currency!

Embraces randomness:
- Does away with the notion of a specific end-point.
- Consensus happens over long time scales - about one hour.
Implicit Consensus

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*Every block contains hash of the block it extends.*
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5. Nodes express their acceptance of the block by including its hash in the next block they create.
Malicious node?

Honest nodes will extend the **longest valid branch**
From merchant’s point of view

Double-spend probability decreases exponentially with # of confirmations

Most common heuristic: 6 confirmations
Summary

- Protection against invalid transactions is cryptographic, but enforced by consensus.
- Protection against double-spending is purely by consensus.
- You are never 100% certain a transaction is in consensus branch. Guarantee is probabilistic.
Assumption of honesty is problematic

Can we give nodes incentives for behaving honestly?

Can we reward nodes that created these blocks?

Can we penalize the node that created this block?
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Can we give nodes incentives for behaving honestly?

Everything so far is just a distributed consensus protocol ... but now we utilize the fact that the currency has value.
Incentive 1: block reward

Creator of block gets to:

- include *special coin-creation transaction* in the block,
- choose recipient address of this transaction.
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*Block creator gets to “collect” the reward only if the block ends up on long-term consensus branch!*
Incentive 2: transaction fees

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- Remainder is a transaction fee and goes to block creator.
- Purely voluntary, like a tip.
Remaining Problems

We still need to answer:

1. How to pick a random node?
2. How to avoid a free-for-all due to rewards?
3. How to prevent Sybil attacks?
Proof of Work

To approximate selecting a random node:

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In proportion to computing power: *proof-of-work*.

In proportion to ownership: *proof-of-stake*. 
Hash Puzzles

To create a block, find nonce such that:

\[ H(nonce \| prev\_hash \| tx \| \ldots \| tx) \] is very small or

\[ H(nonce \| prev\_hash \| merkleRoot < target) \]

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Proof of Work Properties

Property 1: Difficult to compute.
Only some nodes bother to compete - miners.

Property 2: Parameterizable cost.
Nodes automatically re-calculate the target every two weeks.

Goal:
average time between blocks = 10 minutes

Property 3: Trivial to verify.
Nonce must be published as part of block.
Other miners simply verify that $H(nonce_{prev}, hash_{tx}, \ldots, tx) < target$
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Summary

Bitcoin has three types of consensus:

1. Value
2. State
3. Rules
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Next time:
- How do we get from consensus to currency?
- What else can we do with consensus?