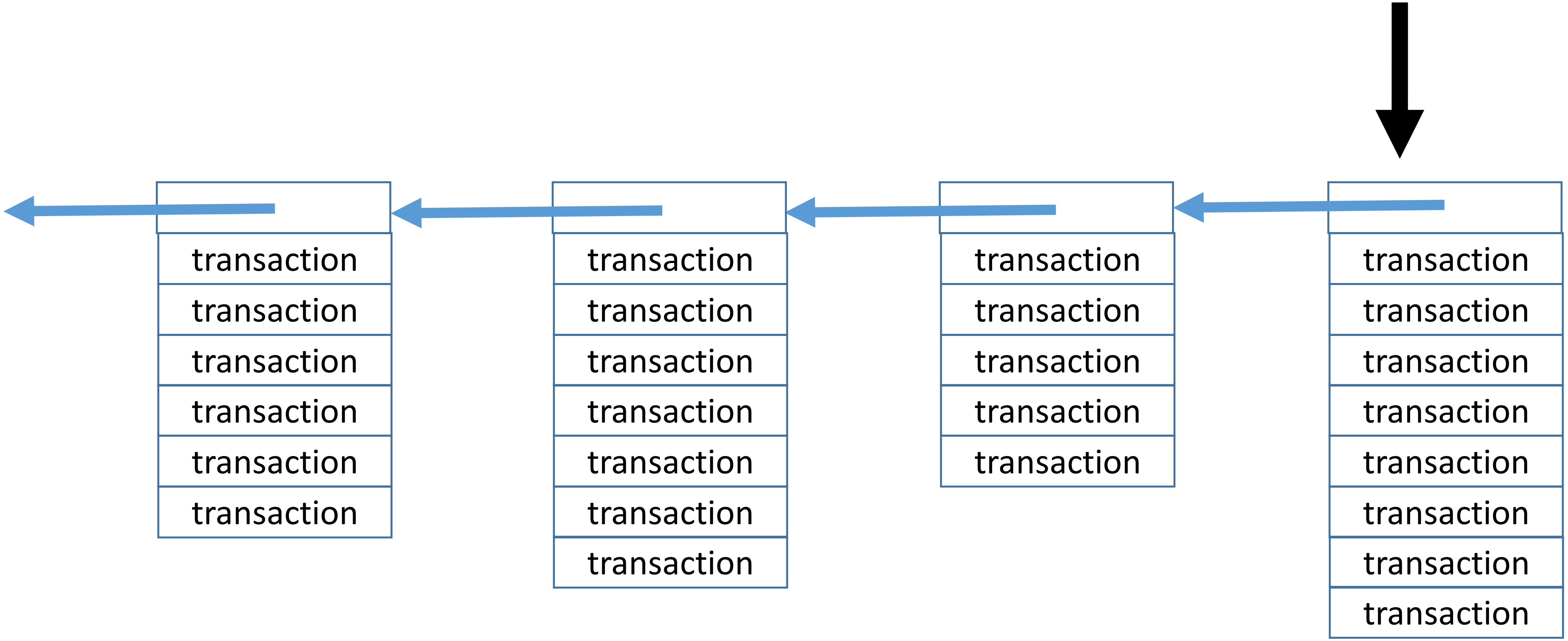
Blockchain and Cryptocurrencies: Technical Background

Ed Felten

Deputy U.S. Chief Technology Officer

OSTP

What is a blockchain?



Newest block is at the end

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Why a blockchain?

- Gives you a public ledger that is tamper-*evident*
  - Any attempt to rewrite history will be detected
- If we assume previously published blocks remain available forever, then ledger is tamper-*proof*

- Doesn’t solve all problems, just those where a public ledger helps

- Not most efficient approach, if you just want to publish information

Who publishes the blocks?

Central authority model:

authority makes blocks, digitally signs them and publishes

Quorum model:

well-known list of authorities

authorities agree “behind the scenes” on contents of next block

authorities sign the agreed-upon block, and publish it

users trust any block signed by a quorum of authorities

Fully decentralized model:

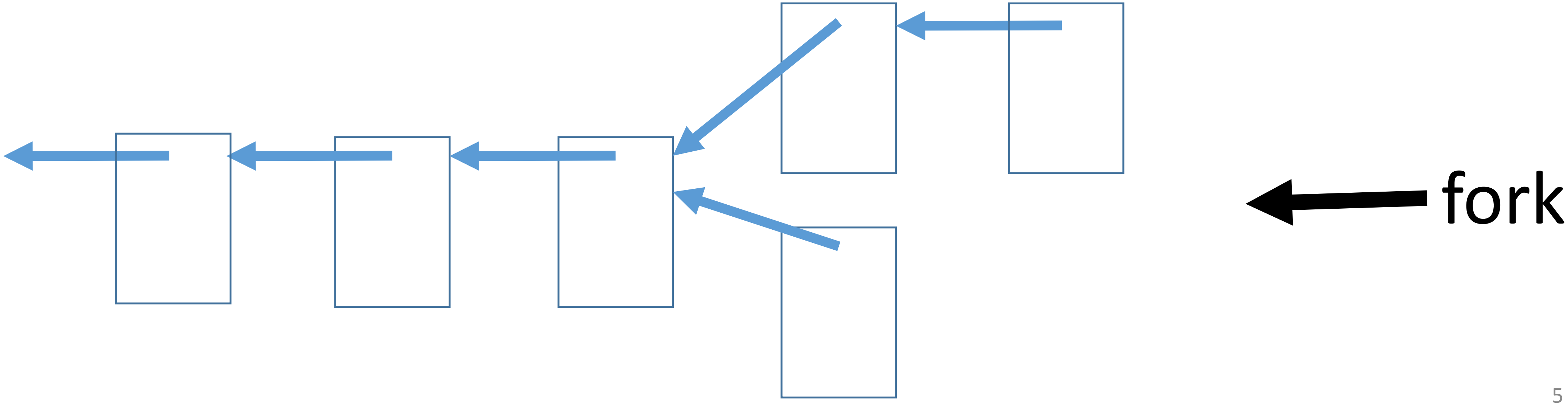
“everyone cooperates” to agree on the next block

Required properties

Liveness: At least one new block is published in every time step.

Consensus: No block has more than one successor.

or: "No forks."



Preventing forks

With a central authority: If we see a fork, punish the authority.

With a quorum system:

If we see a fork, some authority must have misbehaved.

Punish that authority.

Fully decentralized approach: It’s very complicated!

Fully decentralized consensus: why it’s hard

Need all participants to agree on the next block, but:

- Very large number of participants
- Don’t know who they are
- Some might be sock puppets for others
- Participants have incentive to manipulate the outcome
- Participating honestly might be costly (computing, bandwidth, etc.)
- Can’t assume a single legal system that reaches all participants

Seems impossible?

Decentralized consensus: using incentives

Solution concept: design an incentive mechanism so that

- if everyone* rationally maximizes their revenue,
- and assumes that everyone* else rationally maximizes their revenue
- then consensus will result.

Note that the mechanism must be self-enforcing, in the sense that it relies only on cryptographic math and the laws of the universe, not on legal enforcement.

“everyone*” means: almost everyone, a large majority

Nakamoto’s Solution (in Bitcoin)

- Create a blockchain and a digital currency together, each depending on the other (“symbiotic”)

- Use the blockchain to record transfers of the currency
- Use the currency to pay people to make new blocks for the blockchain
  - Key idea: payment contingent on the new block being accepted as valid

- Why it seems* to lead to consensus:
  - If you make a block that forks the chain, it might not be accepted by others
  - If you make a block that doesn’t create a fork, it is more likely to be accepted
  - So your incentive is to avoid making a fork

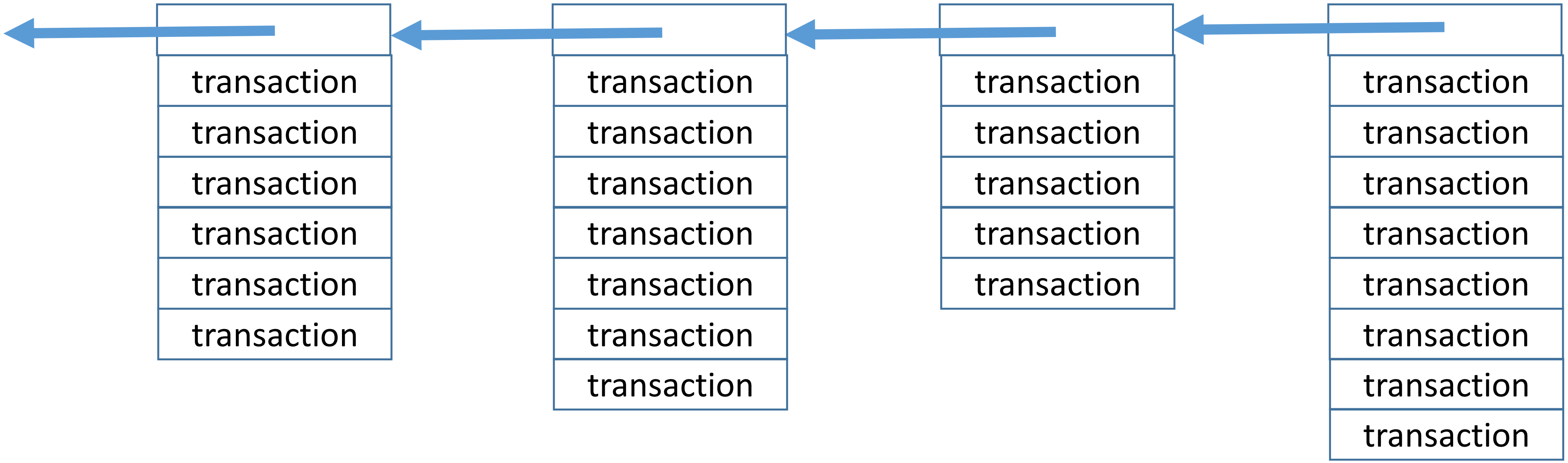
Implications …

Any blockchain must either:

- use a centralized or quorum approach, or
- be symbiotic with a digital currency.

A “bare” blockchain that is fully decentralized is not something we know how to build.

But: what is a valid transaction?



Valid transactions (in Bitcoin)

Payment of Coin C from Person A to Person B: valid if

- Person A owns Coin C, and
- Person A has digitally signed the transaction.

Creation of new coins: valid if

- No more than 25 new coins are created, and
- This is the only coin creation transaction in the current block.

[other transaction types omitted]

What if a transaction is invalid?

If a block contains an invalid transaction, ignore that whole block.

Result: incentive to avoid creating blocks with invalid transactions.

Therefore: A transaction will be accepted as valid if everyone* believes it will be accepted as valid.

Therefore: A transaction validity rule will be enforced if everyone* believes it will be enforced.

Therefore: The rules will change whenever everyone* believes they have changed.

Privacy / Anonymity

- Bitcoin currency and blockchain use “pure pseudonyms.”
  - Pseudonym is just a randomly generated crypto key.
  - Anyone can make a new pseudonym at any time.
  - Anyone can make as many as they like, whenever needed.

- Easy for anyone to “follow the money” because all transactions are published on the blockchain.
- But don’t see identity of actors, only pseudonyms.
  - Crucial question: Can you link pseudonym to identity?
  - Answer: Sometimes; it’s complicated.

Coming soon: Fully anonymous cryptocurrency

- Researchers have discovered fancy crypto tricks that allow fully anonymous cryptocurrency.
  - Blockchain consists entirely of cryptoblobs that nobody can read.
  - But you can:
    - Prove to a third party that you own a coin, and
    - Transfer coins to another party

- Blockchain conveys absolutely nothing of use to an analyst.

- A startup company is building this now.   (Zerocash / Zcash)

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