Introduction to Cryptocurrencies

Haskell and Cryptocurrencies

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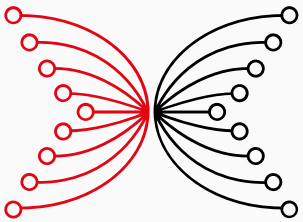


INPUT | OUTPUT

Topics in this Lecture

Topics

- Blockchains & cryptocurrencies —
  - What are they?
  - How do they work?
- IOG in the cryptocurrency world
- Haskell at IOG

What are blockchains?

Short Definition of a Blockchain

A *blockchain* (...) is a distributed database that is used to maintain a continuously growing list of records, called *blocks*. Each block contains a timestamp and a link to a previous block.

Wikipedia

Properties of Blockchains

Blockchains are...

Properties of Blockchains

Blockchains are...

- "write-only" memory in the cloud
- decentralized
- a public ledger
  - for financial transactions
  - for university diplomas (GUNET,...)
  - for property rights (land, houses, cars,...)
  - ...

What are Cryptocurrencies?

Short Definition of a Cryptocurrency

A *cryptocurrency* (or crypto currency) is a digital asset designed to work as a medium of exchange using *cryptography* to secure the *transactions* and to control the *creation of additional units* of the currency.

Andy Greenberg

Properties of Cryptocurrencies

- For us, a cryptocurrency is a blockchain specialized to financial transactions.
- So the ledger entries are *transactions*.
- Units of currency are associated with *public keys*.
- Everybody who knows the *private key* for a given key can control the money associated with that key.

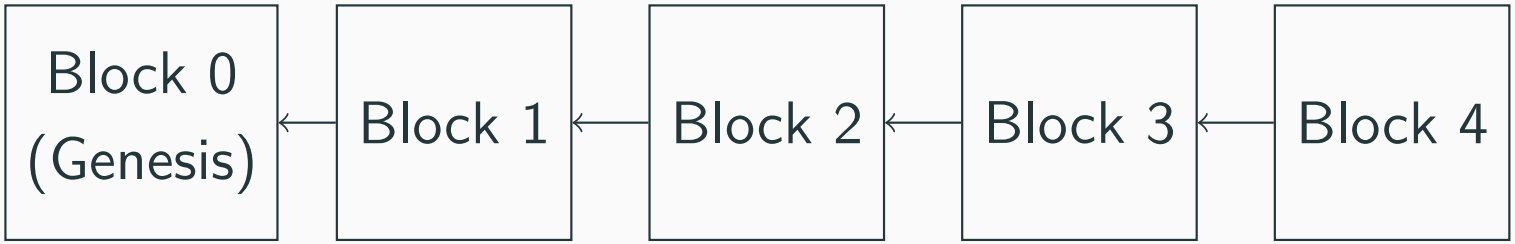
Beyond Generic Blockchains

On top of the generic blockchain protocol, there are mechanisms for

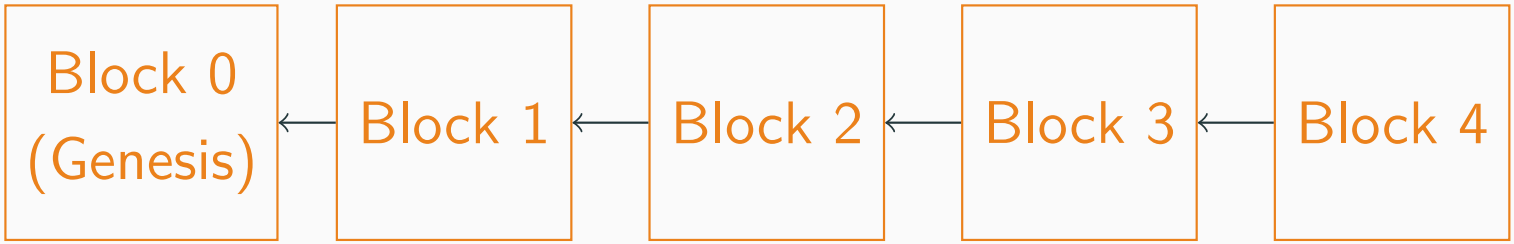
- regulating creation of new coins,
- transaction fees and rewards for block creators,
- smart contracts,
- ...

How Blockchains Work

An Ideal Blockchain



An Ideal Blockchain



Blocks each contain a list of ledger entries (for example transactions) and reference the previous block, thus putting all entries in a linear order.

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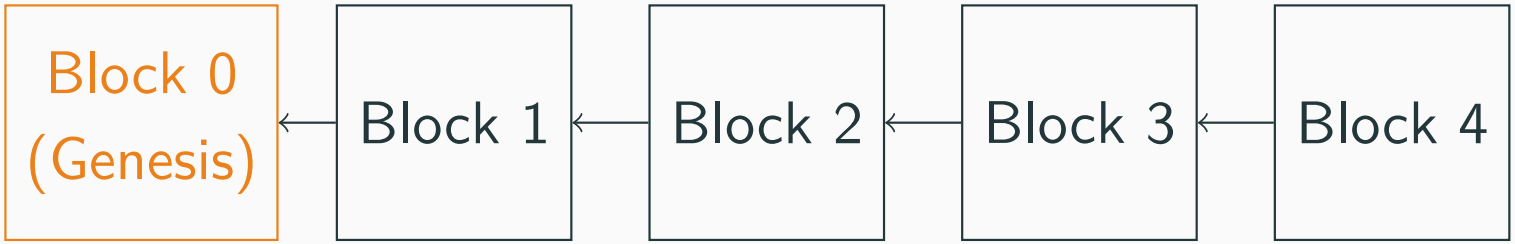

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The first block is called the Genesis Block. It is publicly known and contains the initial state.

Questions and Possible Attacks – Forgery and Manipulation

- How to prevent forgery of ledger entries?
- How to safeguard blocks against tempering?

Cryptographic Hash Functions

A (cryptographically secure) *hash function* is a function H that takes arbitrary bitstrings to bitstrings of a fixed length with the following additional properties:

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- effectively computable
- collision free
- hiding
- (puzzle friendly)

Digital Signatures

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- *Key Generation: genKeys*, given a desired key size, produces a pair of keys (*pk*, *sk*) of the desired lengths.
- *Signing:* given an arbitrary bitstring and a secret key *sk*, function *sign* returns a (fixed length) bitstring, the digital signature.
- *Verification:* Given an arbitrary bitstring, a public key *pk* and a signature, function *verify* checks whether the signature is valid.

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Important

It should be infeasible to "guess" a valid signature for a given message and public key without knowing the private key!

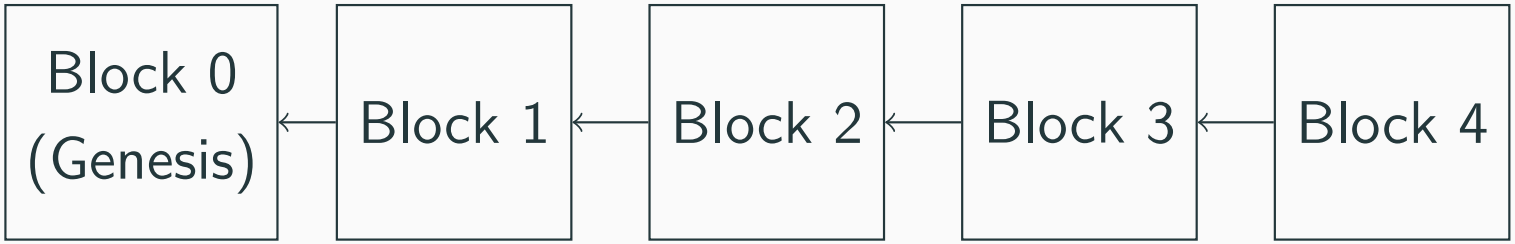
Preventing Forgery with Dital Signatures

- Each ledger entry is digitally signed by somebody with the apropriate rights (for example the owner of the money being transferred).
- Each block is signed by the block creator.

Preventing Blockchain Manipulation with Hashing

- Each block's link to the previous block contains/is the *hash* of the previous block.
- This means it is impossible to delete, insert or change blocks afterwards.

Another Problem: Forking



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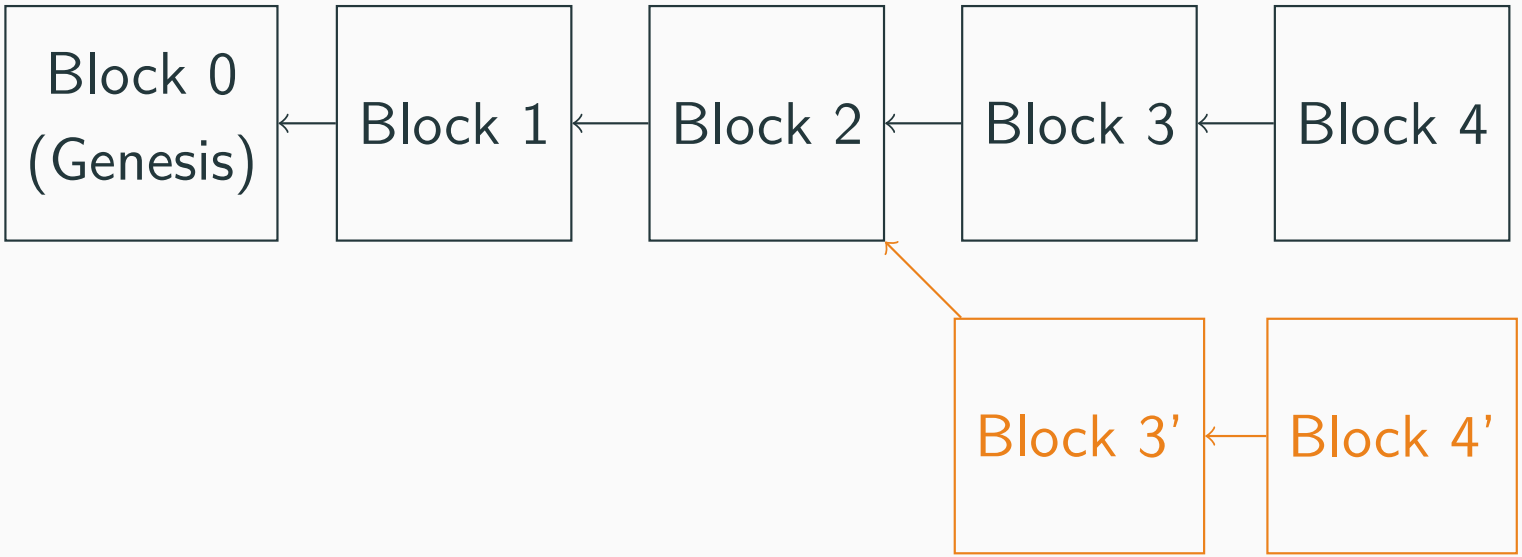

Nothing in the blockchain data structure enforces a *chain*. To prevent forks, something else is needed.

Why Forks are a problem

- The *linear* ordering of all blockchain entries is essential.
- Forks destroy the linear order.
- In the context of cryptocurrencies, a fork means potential for "double spending".

Consensus Protocols

- Even in the absence of malicious players, forks cannot be prevented completely (network errors,...).
- A *Consensus Protocol* ensures that forks do not become too deep.
- *Common Prefix* should hold: After "throwing away" the last k blocks, each party has the same view of the blockchain (longest path in the tree).
- Idea: The right to create blocks is tied to some asset which "mostly" belongs to honest parties.
- For Bitcoin: *Proof-of-Work* (computing power).
- For Ada: *Proof-of-Stake*.

How Cryptocurrencies Work

Transaction Structure

A *transaction* contains the following data:

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- A list of *inputs*, where each input references a previous transaction output.
- A list of outputs. Each output consists of
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- For each input, a *signature* of the transaction by somebody in control of the referenced output.

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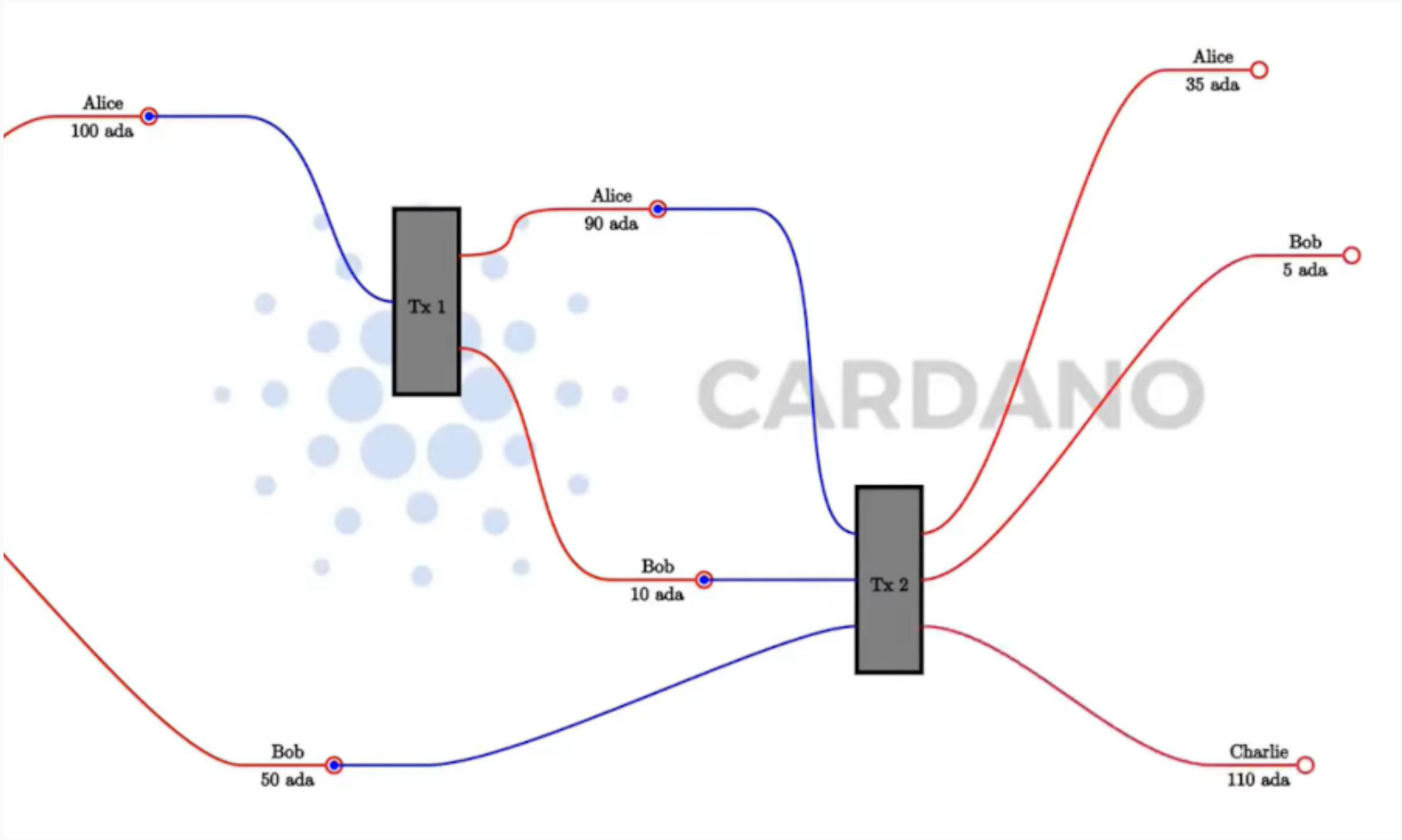
Note

Inputs are always used up completely.

Transaction Structure (Continued)



Valid Transactions

A transaction is *valid* if:

Valid Transactions

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- All input signatures can be verified.
- The sum of input amounts is at least as big as the sum of output amounts.

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- The block creator had the right to create a block at that time (details depend on the consensus protocol).
- The signature of the block creator can be verified.
- All transactions in the block are valid.
- All transactions in the block are consistent: With respect to the linear ordering of transactions in the blockchain, all inputs have not been spent before.

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Note

The first two items above hold for all blockchains, the last two are specific to cryptocurrencies.

Fees and Incentives

- If the sum of input values of a transaction exceeds the sum of output values, the difference is considered as *transaction fees*.
- Whether fees are obligatory depends on the individual cryptocurrency.
- In Bitcoin, the block creator gets the fees.
- In Bitcoin, the block creator also gets a reward for each block, which is implemented as a special “coin base” transaction.

IOG and Cryptocurrencies

IOG Role & Philosophy

- IOG is a “factory for cryptocurrencies”.
- Works on *Ethereum Classic* (in Scala) and *Ada* (in Haskell).
- Employs both academic researches and software developers.
- Is committed to *best practices*, both in academia (peer reviewed papers,...) and sofware development.
- Strives to be as rigorous as possible (mathematical proofs, formal verification,...).
- Develops a “toolbox” for cryptocurrencies, so that different consensus protocols, incentive schemes and other ingredients can be combined easily.
- Wants to get things right. — No cutting corners!

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- is statically typed with a sophisticated type system,
- is *fun*!