Decentralized Execution of Smart Contracts: Agent Model Perspective and Its Implications

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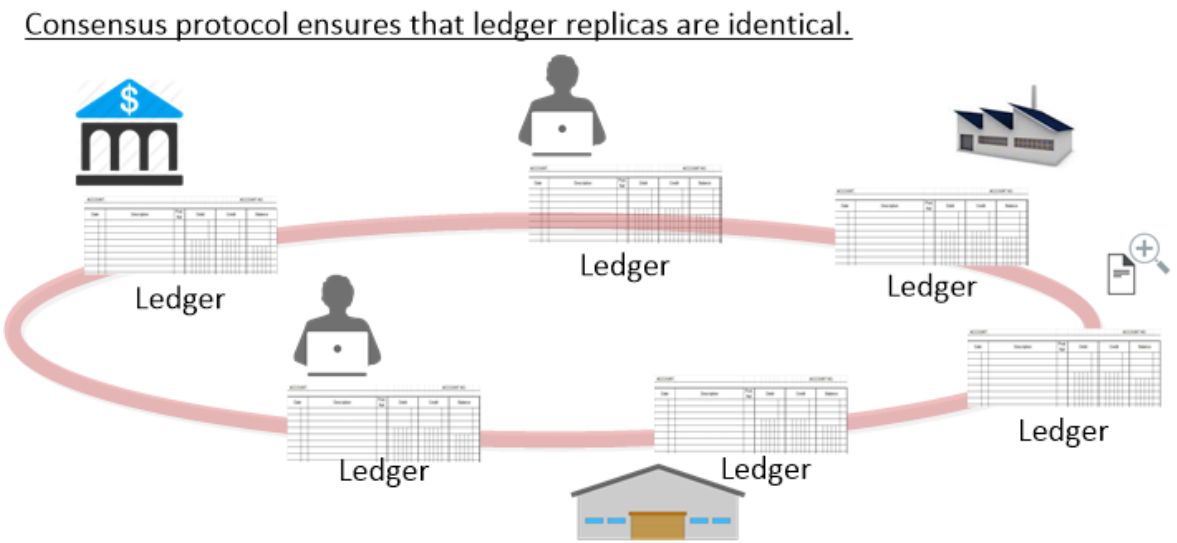
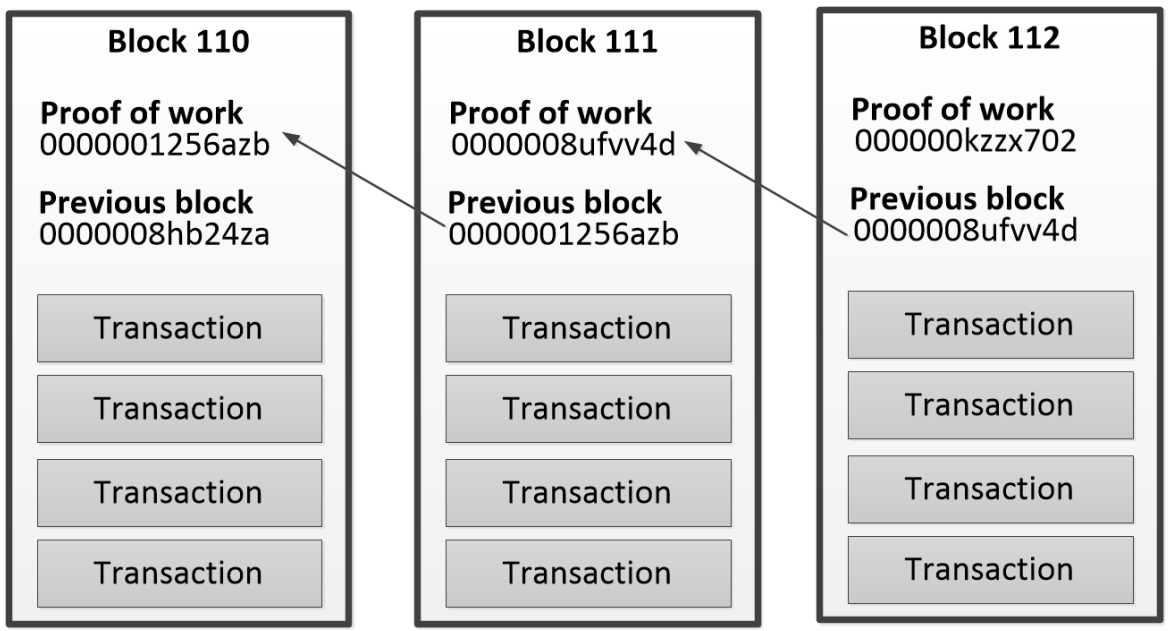
Background

- What is a blockchain?
  - Shared, replicated, ledger.



Background

- A chain of blocks of transactions - examples including:
  - Bitcoin
  - NXT
  - Ethereum
  - ...



Background

- Crypto ledgers (e.g., Ethereum, Hyperledger) aim at supporting "smart contracts".

Definition

A smart contract is a set of promises, specified in a digital form, including protocols within which the parties perform on these promises.

Background

- Another definition:

Definition

A smart contract is an event driven program, with state, which runs on a replicated, shared ledger and which can take custody over assets on that ledger [Swanson2015].

Background

- Abstract smart contract model:
  - Shared public ledger
  - Replicated states (smart contracts)
  - Using crypto-currency rewarding contract execution
  - Contracts involving financial gains or losses
  - Event driven
  - Consensus based (smart contract execution)
  - Participants are not trusted
  - Inter-dependent contracts

Background

- A simple example of a smart contract.

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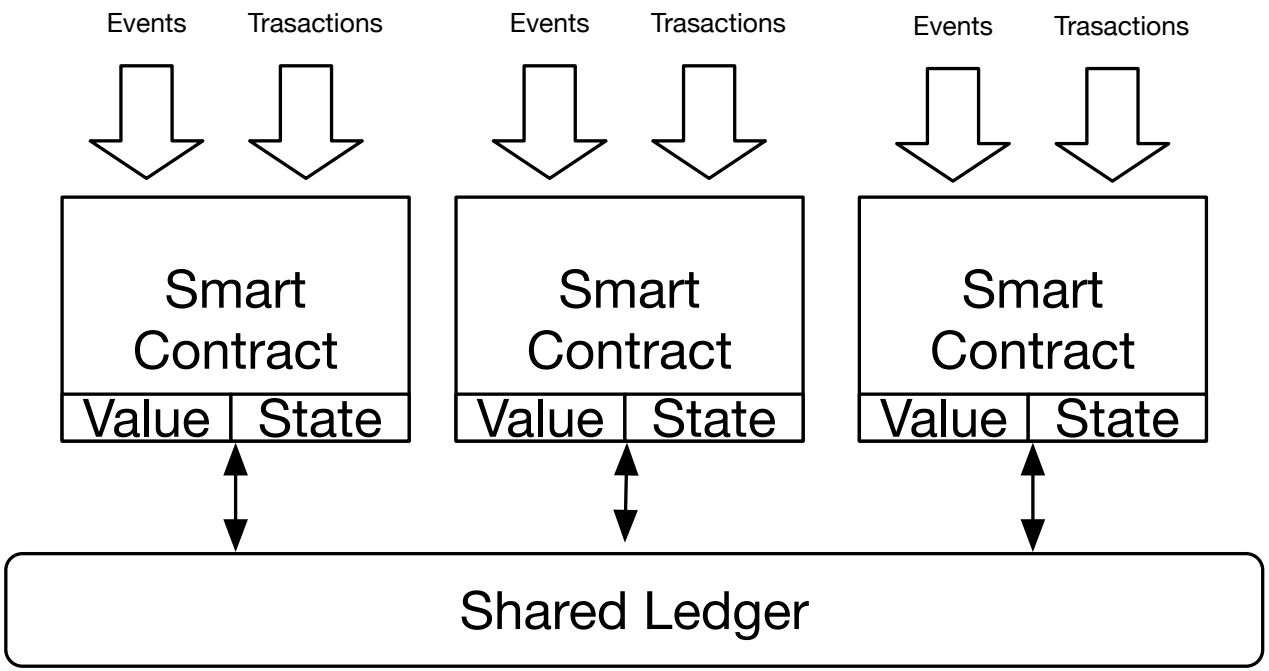
Events
Trasactions
Events
Trasactions
Events
Trasactions
Smart Contract
Value
State
Smart Contract
Value
State
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Shared Ledger

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- If the random dice returns 1, Alice has the incentive of lying.

Background

- Execution of a smart contract can be tricky:
  - The amount of crypto-currency involved in a contract may be many times and significantly higher than the cost of running the contract itself.
  - If a significant portion of users in system are directly or indirectly involved in a smart contract, then this smart contract might not get executed correctly.

The problem

- A game theoretical model (smart contract participants and execution nodes are agents):
  - N players (users in the system)

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    - Longest chain: adding blocks after a specific chain
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  - A state receiving αW votes in weight wins

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Q: Can we prevent users from lying when they vote?

Our contribution

- In general, lying can not be prevented.

Lemma

Voting for the state that a user prefers the most is his/her dominant strategy.

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Lemma

Voting for the state that a user prefers the most is his/her dominant strategy.

- Can we discourage users from lying by adding punishment?

Our contribution

- The system can impose a penalty on a user if his/her vote is different from the accepted state.

Theorem

In the agent model with penalty, if j is superrational and knows that $\sum_{k \in U} w_k \geq \alpha W$, then no matter how high the penalty is, j will always lie.

Our contribution

- The classical game theory seems to lead us nowhere...

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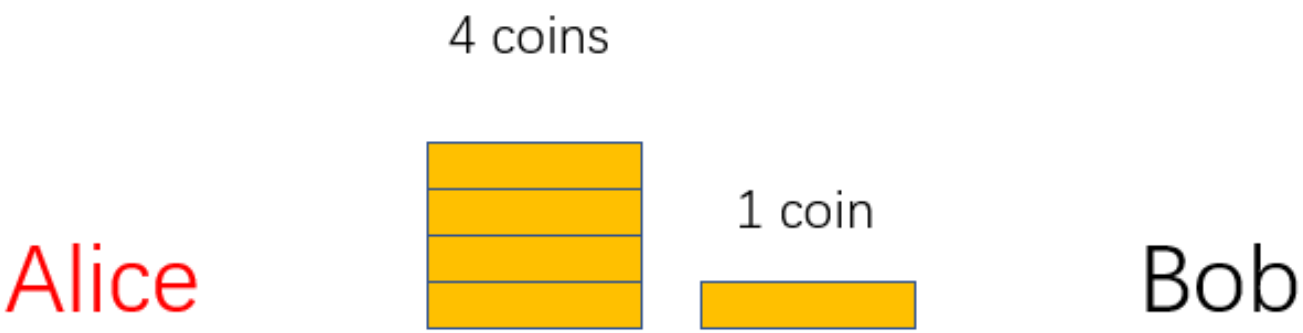
- The classical game theory seems to lead us nowhere...
- But rationality or superrationality is questionable.

Irrational behaviors

- Centipede game:



Alice can: Take the pile of 4 coins, or pass both piles to Bob

Irrational behaviors

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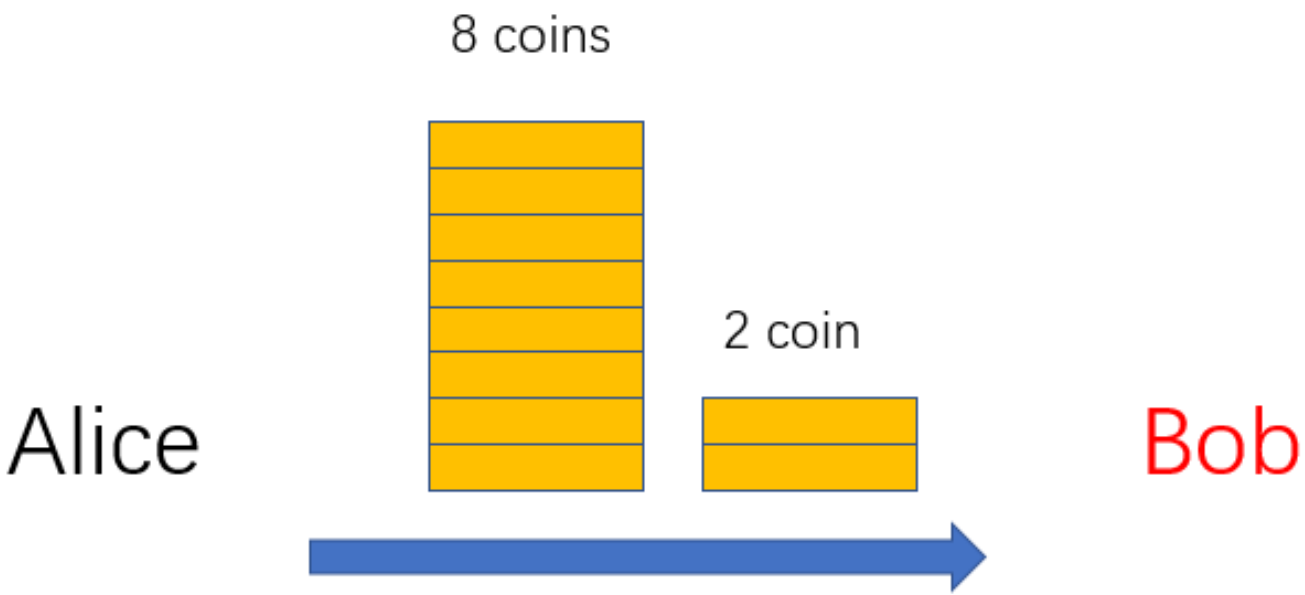

The coins double if Alice chooses to pass them to Bob, but then it becomes Bob's turn to decide.

Irrational behaviors

- Centipede game
  - The game lasts for a fixed number of rounds, which is known to both players.
  - A rational player chooses to take the larger pile and the game ends immediately. Only 15% players choose to do so in experiments.

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Theorem

In the agent model with penalty, if users do not fully believe in the rationality of others, then a mechanism with penalty can be designed such that users do not lie in voting.

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- Truthfulness of users can not be achieved if rationality or superrationality is assumed, even if penalty is introduced.
- Truthfulness of users can be achieved with a carefully designed penalty, if irrationality is assumed.