Exploring Incentives in Cardano

Enabling Fair Decentralised Systems
Blockchain for Coders - Crypto Valley

Dr. Lars Brünjes, Director of Education at IOHK

2018-11-08

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About myself

- PhD in Pure Mathematics from Regensburg University (Germany).
- Postdoc at Cambridge University (UK).
- Ten years working in Sofware Development prior to joining IOHK.
- Haskell enthusiast for more than 15 years.
- Joined IOHK November 2016.
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- Director of Education at IOHK: Haskell courses (Athens, Barbados, Addis Abeba, ...), internal and external trainings,...
- Leading the "Incentives" workstream.

The people doing all the hard work...

Prof. Aggelos Kiayias, University of Edinburgh (UK), Chief Scientist at IOHK

Prof. Elias Koutsoupias, University of Oxford (UK), Senior Research Fellow at IOHK

Aikaterini-Panagiota Stouka, University of Edinburgh (UK), Researcher at IOHK

Introduction

What are incentives?

Incentives in the context of a cryptocurrency are ways of encouraging people to participate in the protocol and to follow it faithfully.

In the case of Bitcoin, this means mining blocks and including as many valid transactions in those blocks as possible.

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In the case of Cardano, it means being online and creating a block when they have been elected slot leader and to participate in the election process.

What are incentives?

Incentives in the context of a cryptocurrency are ways of encouraging people to participate in the protocol and to follow it faithfully.

Participating in the Cardano protocol encurs far less computational costs than participating in Bitcoin.
Nevertheless, having slot leaders online when it is their turn is important for both security and efficiency.

Monetary incentives

In this talk, when we talk about incentives, we mean monetary incentives in the form of ADA.

In exchange for participating in the protocol and supporting the efficient operation of the system, stakeholders get rewarded by a certain amount of ADA.

Other types of incentives

However, it should be noted that there are other types of incentives as well: things like idealism and morality and the general desire to ”do the right thing”.

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For example, when the Bitcoin mining pool Ghash.io accumulated 42% of total mining power, people voluntarily started leaving the pool and brought it down to 38% in only two days.

(CoinDesk, 2014-01-09)

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The people who left Ghash.io did not receive any Bitcoin for leaving.
Rather, they believed that concentrating too much mining power was *bad* and that leaving was *the right thing to do*.

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Ideal

Monetary and moral incentives should align perfectly.

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The above example shows that in Bitcoin, this ideal is not always achieved.
Sometimes people have to choose between doing the morally right thing and pursuing their financial gain.

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Our goal

In Cardano, we strive for perfect alignment of incentives.

Incentivized behavior in Cardano

As mentioned above, we want to incentivize stakeholders to be online when they have to participate in the protocol (for example to create a block).

People who lack the interest, technical know-how or time to be online when needed can still participate by delegating their stake to a stake pool.

Desired configuration

For maximal efficiency and security, a solid majority of stake (ca. 80%) should be delegated to a number of k stake pools ($k \sim 1000$ seems to be reasonable).

The stake pools should be online when needed, and they should provide additional network infrastructure (”relay nodes”).

The remaining ca. 20% should belong to ”small” stake holders, who can decide to either participate in the protocol on their own or to simply do nothing.

Delegation

The people behind the delegation mechanism

Dimitris Karakostas, University of Edinburgh (UK), Researcher at IOHK

Prof. Aggelos Kiayias, University of Edinburgh (UK), Chief Scientist at IOHK

Dr. Mario Larangeira, Tokyo Institute of Technology (Japan), Research Fellow at IOHK

Delegating stake in Cardano

Cardano is a Proof of Stake system, so holding stake, i.e. owning ADA, means more than holding Bitcoin means for the Bitcoin protocol.

Cardano is a fully-fledged cryptocurrency, so of course ADA can be used to buy goods or services.

In addition to that, holding ADA also comes with the right (and obligation!) to participate in the protocol and to create blocks.

These two uses of holding ADA can be separated via delegation: A stakeholder can delegate her right to protocol participation while retaining the monetary value.

Control over funds

Note

The act of delegation does not relinquish spending power.
Only the right to participate in the protocol is delegated.
Funds can be spend normally at any time.

Stake pool registration

Somebody wanting to create a stake pool creates a registration certificate and embeds it in a transaction that pays the pool registration fees to a special address.

The certificate contains the staking key of the pool leader (in addition to some meta information like pool costs).

People wishing to delegate to the pool must create delegation certificates delegating their stake to that key.

Scenarios

Using combinations of base- and pointer addresses and ”chains” of delegation certificates, a large number of scenarios can be covered, including

- regular user wallets
- offline user wallets with cold staking
- wallets with enhanced privacy
- staking pool wallets
- enterprise (exchange) wallets

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- enterprise (exchange) wallets

Note

For exchange wallets, staking will not be possible. Exchanges are not supposed to use funds entrusted to them for protocol participation.

Mechanism

Transaction fees

There are two main reasons for having transaction fees in Cardano (or any other cryptocurrency):

- The prevention of DDoS (Distributed Denial of Service) attacks. In a DDoS attack, an attacker tries to flood the network with dummy transactions, and if he has to pay a sufficiently high fee for each of those dummy transactions, this form of attack will become prohibitively expensive for him.
- Important for this talk: To provide funds for incentives.

How transaction fees work

Whenever somebody wants to transfer an amount of Ada, some minimal fees are computed for that transaction.

In order for the transaction to be valid, these minimal fees have to be included, although the sender is free to pay higher fees if he so wishes.

Minimal fees

The minimal fees for a transaction are calculated according to the formula:

$$a + b \times size$$

where:

- a is a special constant, at the moment it is 0.155381 ADA;
- b is a special constant, at the moment it is 0.000043946 ADA/byte;
- $size$ is the size of the transaction in bytes.

For example, a transaction of size 200 bytes (a fairly typical size) costs:

$$\begin{aligned} 0.155381\ \mathrm{ADA} + 0.000043946\ \mathrm{ADA/byte} \times 200\ \mathrm{byte} \\ = 0.1641702\ \mathrm{ADA}. \end{aligned}$$

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The reason for having parameter a is the prevention of DDoS attacks mentioned above: Even a very small dummy transaction should cost enough to hurt an attacker who tries to generate many thousands of them.

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Parameter b has been introduced to reflect actual costs: Storing larger transactions needs more computer memory than storing smaller transactions, so larger transactions should be more expensive than smaller ones.

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Although particular values for parameters a and b were calculated, these values will probably be adjusted in future to better reflect actual costs.

Monetary expansion

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Justification

Over time, when more and more people use Cardano, more and more transaction fees will be available to compensate for the decrease in monetary expansion.

Example of exponential decrease

For an arbitrary example of exponential decrease, we could set the policy of using 5% of the remaining ADA per year for incentives:

year	used for incentives	remaining
1	700,000,000	13,300,000,000
2	665,000,000	12,635,000,000
3	631,750,000	12,003,250,000
4	600,162,500	11,403,087,500
5	570,154,375	10,832,933,125
6	541,646,656	10,291,286,469
7	514,564,323	9,776,722,145
8	488,836,107	9,287,886,038
9	464,394,302	8,823,491,736

Incentives distribution

In Cardano, time is divided into epochs and slots.

A slot lasts 20 seconds, an epoch contains 21,600 slots and lasts five days.

Incentives are distributed on an epoch by epoch base: All transaction fees of the blocks created during the epoch (together with ADA from monetary expansion) are collected into a virtual rewards pool; then this pool is distributed amongst the stakeholders.

Basic idea of distribution

The rewards pool from one epoch is distributed amongst stake pools (and individual protocol participants) according to their stake.

There are two conceivable ways of doing this:

- Proportional to stake controlled at the beginning of that epoch.
- Proportional to the number of slots the stake pool was *elected* slot leader (*not* to the number of blocks created).

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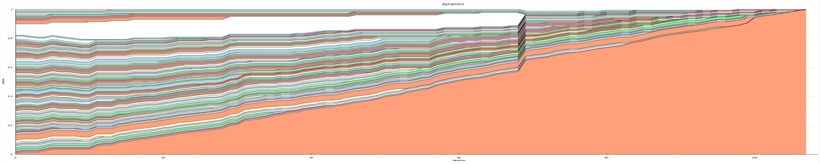
Note

Due to how the Cardano protocol works, these methods have the same expected reward, because the probability of being elected slot leader is proportional to the controlled stake.

Problem with the basic idea

The basic idea is a good guideline, but too naive: The fewer pools there are, the lower total costs will be, the higher everybody's rewards will be.

So the system will tend towards a single dictatorial pool that everybody else delegates to.



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As a first refinement to the basic idea, the maximal proportion of the rewards pool that a stake pool can receive will be limited by $1/k$, where k is the number of desired pools ($k \sim 1000$).

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Example

Let us assume $k = 1000$, and consider stake pools A and B with 0.03% and 0.12% of stake respectively. Then A will receive 0.03% of the rewards pool, but B will only receive 0.1% instead of 0.12%.

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Motivtion

This policy should prevent stake pools from growing too large.

Second refinement: being online

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Eligibility

As a consequence, there will be a predicate that, looking at the slots a given stake pool was elected for as leader and the number of blocks it actually created, will decide whether the stake pool is eligible for its share of the rewards pool.

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Remark

This predicate might also not be all-or-nothing, but instead award a certain percentage of available rewards based on adherence to the protocol.

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Thus stake pools should be penalized for not following the protocol and not being online when it is their turn.

Note

The predicate can not be as simple as ”created at least x% of the blocks it was supposed to”, because this could lead to nobody being online towards the end of an epoch.

Undistributed funds

Note that the two refinements explained before can lead to a situation where not all funds contained in the rewards pool will be distributed.

This, however, is a feature, not a bug, because the remaining funds can instead be put to use in the treasury.

No competition

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Consequence

There is no incentive for any pool to sabotage another pool's work.

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Selfish mining

Attacks like selfish mining or block withholding can not work, because the pools are ”fenced off” from each other. The actions of one pool only affect its own rewards.

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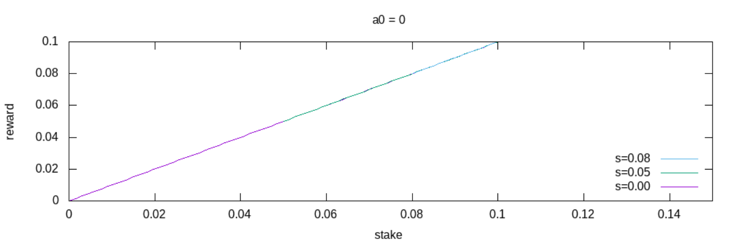

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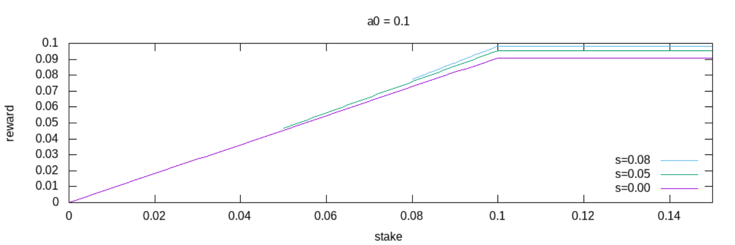

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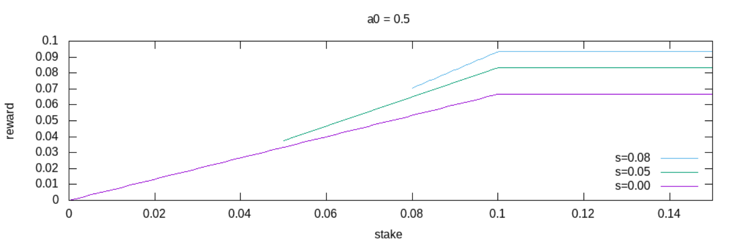

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The way this happens should follow two guidelines:

- The pool leader herself should be compensated for her costs (computing power, online time) and rewarded for her efforts.
- Pool members should be rewarded proportional to the stake they delegated to the pool.

Example

As an arbitrary example, consider pool leader Alice with 0.2% of stake, who forms her pool with Bob (0.1% of stake) and Charlie (0.2% of stake).

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Of the 25,000 ADA, Bob will get half of what Charlie gets, but Charlie will get less than Alice herself, to reward Alice for the cost and trouble of running her pool.

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If Alice gets an additional 5,000 ADA for her trouble, she would end up with 13,000 ADA, Bob with 4,000 ADA and Charlie with 8,000 ADA.

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Note

This example is purely fictional and meant to explain the idea of reward distribution. It by no means reflects future actual

For mathematicians, a game is a system where players can choose between strategies, and the payoff of each player is determined by his and everybody else's strategy.

Example: Prisoner's Dilemma

Two players A and B, each having two strategies ”stay silent” and ”betray” with the following payoff matrix:

	B stays silent	B betrays
A stays silent	-1/-1	-3/0
A betrays	0/-3	-2/-2

So for example, if A stays silent and B betrays, then A's payoff will be -3, and B's will be 0.

Nash Equilibrium

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- Any (reasonably well behaved) game has at least one Nash Equilibrium.
- Games played by *rational* players ”tend” to end up in a Nash Equilibrium.
- An important step in understanding a game is therefore understanding its Nash Equilibria.

Nash Equilibrium for the Prisoner's Dilemma

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- If one player stays silent, he can always improve his payoff by betraying (provided the other player doesn't change his strategy).
- If both players betray, none has incentive to unilaterally change to staying silent.
- Therefore both players betraying is the (unique) Nash Equilibrium of the Prisoner's Dilemma.

The staking game

We consider the game where players' strategies are

- Opening a staking pool with a specific margin.
- Delegating stake to other pools.

Fourth refinement: not being short sighted

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Fourth refinement: not being short sighted

- There is a problem with this ”staking game”!
- It would always be profitable for a pool operator to change his strategy and increase his margin!
- In reality, of course, pool operators will know that people will leave their pools if they do that.
- So we refined the game by ”looking ahead” and taking into account that only the k most attractive pools will actually have members.

With all refinements

With all refinements in place...

...we prove:

- Each (approximate) Nash Equilibrium will consist of k pools with $1/k$ stake each.
- If $a_0 = 0$ (no Sybil protection), those k pools will be run be the k players with the lowest *cost*.
- For $a_0 > 0$, they will be run by the players with the ”most favourable” combination of pledged stake and cost.

With all refinements

With all refinements in place...

Reward Sharing Schemes for Stake Pools

Lars Brünjes[*] Aggelos Kiayias[†] Elias Koutsoupias[‡] Aikaterini-Panagiota Stouka[†]

Saturday 13$^{\text{th}}$ October, 2018

Abstract

We introduce and study reward sharing schemes that promote the fair formation of *stake pools* in collaborative projects that involve a large number of stakeholders such as the maintenance of a proof-of-stake (PoS) blockchain. Our mechanisms are parameterised by a target value for the desired number of pools. We show that by properly incentivising participants, the desired number of stake pools is a non-myopic Nash equilibrium arising from rational play. Our equilibria also exhibit an efficiency / security tradeoff via a parameter that allows them to be calibrated and include only the pools with the smallest possible cost or provide protection against Sybil attacks, the setting where a single stakeholder creates a large number of pools in the hopes to dominate the collaborative project. We also experimentally demonstrate the reachability of such equilibria in dynamic environments where players react to each others strategic moves over an indefinite period of interactive play, while showing how simple reward sharing schemes, such that inspired

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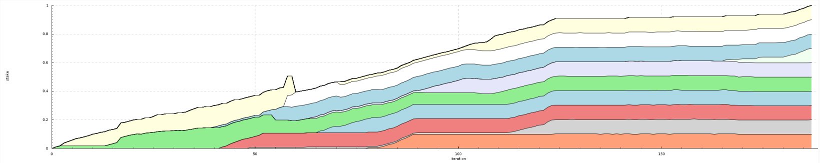

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