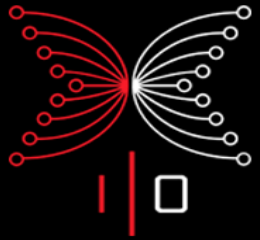
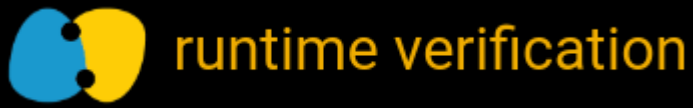
Cardano

The Secret of Success of one of the Leading Cryptocurrencies

BlockLab Rotterdam
2018-10-19

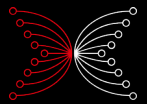




About myself

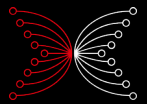
Dr. Lars Brünjes, Director of Education at IOHK

- PhD in Pure Mathematics from Regensburg University.
- Postdoc at Cambridge University (UK).
- Ten years working in Software Development prior to joining IOHK.
- Haskell enthusiast for more than 15 years.
- Joined IOHK November 2016.
- Taught Haskell courses (Athens, Barbados, Addis Ababa,...), internal and external trainings,...
- Working with Formal Methods team.
- Leading Incentives team.



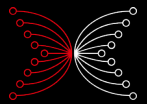
Agenda

- IOHK
- Cardano
- Formal Methods
- Incentives
- Smart Contracts
- Demo: Ouroboros BFT in Haskell



IOHK

Providing financial services to the three billion people that don’t have them.



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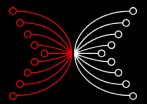

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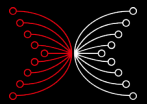

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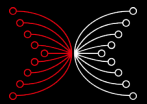

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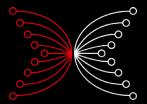

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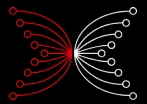
- **Research focused (peer-reviewed research, research centers, ...)**



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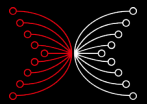
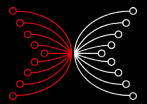


Cardano

- Proof of Stake blockchain



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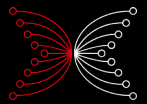
- Cryptocurrency Ada



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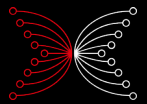
- Roadmap: https://cardanoroadmap.com/



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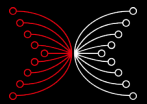

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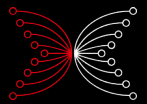

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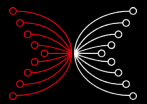
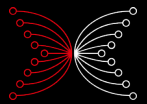
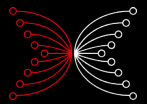


PoW vs PoS



PoW vs PoS

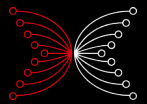
- Leader selection based on Hashing Power: “One CPU, one vote!”
- Leader selection based on Stake: “Follow the Satoshi!”



PoW vs PoS

- Leader selection based on Hashing Power: “One CPU, one vote!”
- Huge energy consumption to guarantee security.

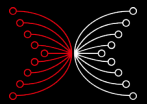
- Leader selection based on Stake: “Follow the Satoshi!”
- Consensus is relatively cheap.



PoW vs PoS

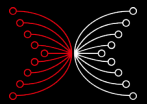
- Leader selection based on Hashing Power: “One CPU, one vote!”
- Huge energy consumption to guarantee security.
- Well established and provably secure.

- Leader selection based on Stake: “Follow the Satoshi!”
- Consensus is relatively cheap.
- Provably secure, but hotly debated.



Ouroboros

First Provably Secure PoS Protocol



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First Provably Secure PoS Protocol

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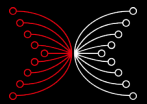

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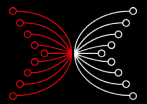
- Elect leader for each time-slot based on stake.
- Stakeholders agree on randomness for next epoch.



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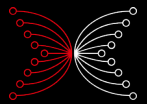
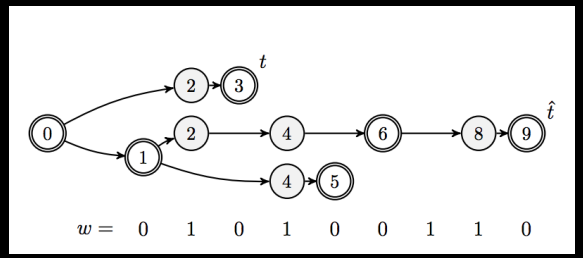
- Running in production in Cardano since October 2017.



Ouroboros

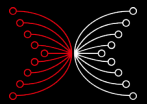
First Provably Secure PoS Protocol

- Elect leader for each time-slot based on stake.
- Stakeholders agree on randomness for next epoch.
- Running in production in Cardano since October 2017.
- Provably secure against adversary with less than 50% stake.



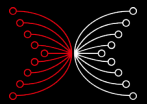
Adversary	BTC	OB Covert	OB General
0.10	50	3	5
0.15	80	5	8
0.20	110	7	12
0.25	150	11	18
0.30	240	18	31
0.35	410	34	60
0.40	890	78	148
0.45	3400	317	663

Ouroboros Praos



Ouroboros Praos

- Extension of Ouroboros to semi-synchronous setting.



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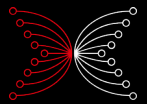
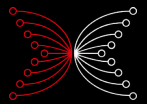
- Extension of Ouroboros to semi-synchronous setting.
- Deals gracefully with message delays.

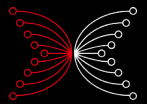


Ouroboros Praos

- Extension of Ouroboros to semi-synchronous setting.
- Deals gracefully with message delays.
- Currently being implemented for future versions of Cardano.

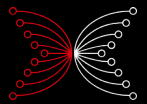


Ouroboros Genesis



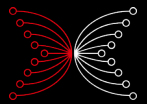
Ouroboros Genesis

- No checkpointing: New Players can safely join the protocol without any trusted advice.

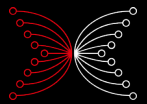


Ouroboros Genesis

- No checkpointing: New Players can safely join the protocol without any trusted advice.
- Security Proof in the UC-framework, making it easier to compare with Bitcoin (and other PoW systems).



Formal Methods



From Mathematical Paper...

Ouroboros Praos: An adaptively-secure, semi-synchronous proof-of-stake blockchain

Bernardo David*, Peter Gaži**, Aggelos Kiayias***, and Alexander Russell†

October 6, 2017

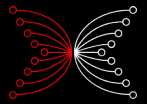
Abstract. We present "Ouroboros Praos", a proof-of-st
the first time, provides security against *fully-adaptive cor
setting*: Specifically, the adversary can corrupt any partic
population of stakeholders at any moment as long the st
an honest majority of stake; furthermore, the protocol tol
message delivery delay unknown to protocol participants.
To achieve these guarantees we formalize and realize in th
suitable form of forward secure digital signatures and a new
that maintains unpredictability under malicious key genera
a general combinatorial framework for the analysis of se
may be of independent interest. We prove our protocol sec
assumptions in the random oracle model.

Protocol π_{SPoS}

The protocol π_{SPoS} is run by stakeholders $U_1, \ldots, U_n$ interacting among themselves and with ideal functionalities $\mathcal{F}_{\mathsf{INIT}}, \mathcal{F}_{\mathsf{VRF}}, \mathcal{F}_{\mathsf{KES}}, \mathcal{F}_{\mathsf{DSIG}}, \mathsf{H}$ over a sequence of slots $S = \{sl_1, \ldots, sl_R\}$. Define $T_i \triangleq 2^{\ell_{\mathsf{VRF}}}\phi_f(\alpha_i)$ as the threshold for a stakeholder U_i, where α_i is the relative stake of U_i, ℓ_{VRF} denotes the output length of $\mathcal{F}_{\mathsf{VRF}}$, f is the active slots coefficient and ϕ_f is the mapping from Definition 1. Then π_{SPoS} proceeds as follows:

1. **Initialization.** The stakeholder U_i sends $(\mathsf{KeyGen}, sid, U_i)$ to $\mathcal{F}_{\mathsf{VRF}}$, $\mathcal{F}_{\mathsf{KES}}$ and $\mathcal{F}_{\mathsf{DSIG}}$; receiving $(\mathsf{VerificationKey}, sid, v_i^{\mathrm{vrf}})$, $(\mathsf{VerificationKey}, sid, v_i^{\mathrm{kes}})$ and $(\mathsf{VerificationKey}, sid, v_i^{\mathrm{dsig}})$, respectively. Then, in case it is the first round, it sends $(\mathsf{ver\_keys}, sid, U_i, v_i^{\mathrm{vrf}}, v_i^{\mathrm{kes}}, v_i^{\mathrm{dsig}})$ to $\mathcal{F}_{\mathsf{INIT}}$ (to claim stake from the genesis block). In any case, it terminates the round by returning $(U_i, v_i^{\mathrm{vrf}}, v_i^{\mathrm{kes}}, v_i^{\mathrm{dsig}})$ to $\mathcal{Z}$. In the next round, U_i sends $(\mathsf{genblock\_req}, sid, U_i)$ to $\mathcal{F}_{\mathsf{INIT}}$, receiving $(\mathsf{genblock}, sid, \mathbb{S}_0, \eta)$ as the answer. U_i sets the local blockchain $\mathcal{C} = B_0 = (\mathbb{S}_0, \eta)$ and its initial internal state $st = H(B_0)$.
2. **Chain Extension.** After initialization, for every slot $sl_j \in S$, every online stakeholder U_i performs the following steps:
   (a) U_i receives from the environment the transaction data $d \in \{0,1\}^*$ to be inserted into the blockchain.
   (b) U_i collects all valid chains received via diffusion into a set $\mathbb{C}$, pruning blocks belonging to future slots and verifying that for every chain $\mathcal{C}' \in \mathbb{C}$ and every block $B' = (st', d', sl', B_{\pi'}, \sigma_{sl'}) \in \mathcal{C}'$ it holds that the stakeholder who created it is in the slot leader set of slot sl' (by parsing $B_{\pi'}$ as (U_s, y', π') for some s, verifying that $\mathcal{F}_{\mathsf{VRF}}$ responds to $(\mathsf{Verify}, sid, \eta \,\|\, sl', y', \pi', v_s^{\mathrm{vrf}})$ by $(\mathsf{Verified}, sid, \eta \,\|\, sl', y', \pi', 1)$, and that $y' < T_s$), and that $\mathcal{F}_{\mathsf{KES}}$ responds to $(\mathsf{Verify}, sid, (st', d', sl', B_{\pi'}), sl', \sigma_{sl'}, v_s^{\mathrm{kes}})$ by $(\mathsf{Verified}, sid, (st', d', sl', B_{\pi'}), sl', 1)$. U_i computes $\mathcal{C}' = \mathsf{maxvalid}(\mathcal{C}, \mathbb{C})$, sets $\mathcal{C}'$ as the new local chain and sets state $st = H(\mathrm{head}(\mathcal{C}'))$.
   (c) U_i sends $(\mathsf{EvalProve}, sid, \eta \,\|\, sl_j)$ to $\mathcal{F}_{\mathsf{VRF}}$, receiving $(\mathsf{Evaluated}, sid, y, \pi)$. U_i checks whether it is in the slot leader set of slot sl_j by checking that $y < T_i$. If yes, it generates a new block $B = (st, d, sl_j, B_\pi, \sigma)$ where st is its current state, $d \in \{0,1\}^*$ is the transaction data, $B_\pi = (U_i, y, \pi)$ and σ is a signature obtained by sending $(\mathsf{USign}, sid, U_i, (st, d, sl_j, B_\pi), sl_j)$ to $\mathcal{F}_{\mathsf{KES}}$ and receiving $(\mathsf{Signature}, sid, (st, d, sl_j, B_\pi), sl_j, \sigma)$. U_i computes $\mathcal{C}' = \mathcal{C}|B$, sets $\mathcal{C}'$ as the new local chain and sets state $st = H(\mathrm{head}(\mathcal{C}'))$. Finally, if U_i has generated a block in this step, it diffuses $\mathcal{C}'$.
3. **Signing Transactions.** Upon receiving $(\mathsf{sign\_tx}, sid', tx)$ from the environment, U_i sends $(\mathsf{Sign}, sid, U_i, tx)$ to $\mathcal{F}_{\mathsf{DSIG}}$, receiving $(\mathsf{Signature}, sid, tx, \sigma)$. Then, U_i sends $(\mathsf{signed\_tx}, sid', tx, \sigma)$ back to the environment.

Fig. 4: Protocol π_{SPoS}.



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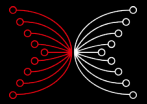

From Mathematical Paper...

Ouroboros Praos: An adaptively-secure, semi-synchronous proof-of-stake blockchain

Bernardo David*, Peter Gaži**, Aggelos Kiayias***, and Alexander Russell†

October 6, 2017

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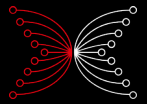

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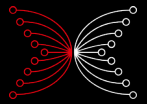

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-- CHECK: @verifyEncShare
-- | Verify encrypted shares
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    :: MonadRandom m
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    -> Scrape.Threshold
    -> [(VssPublicKey, EncShare)]
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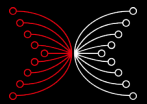

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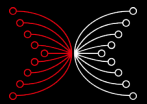

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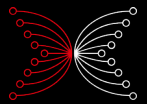

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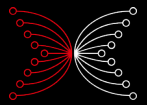

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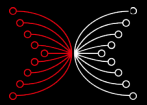

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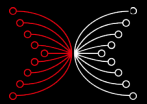

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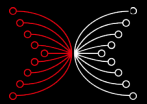

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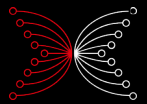

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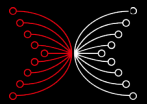

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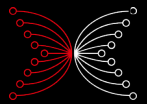

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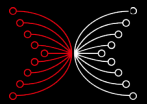

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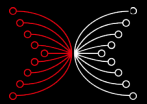

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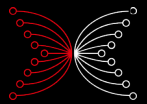

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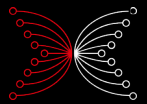
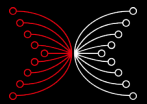
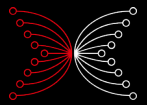


The Solution: Formal Methods



The Solution: Formal Methods

Scientific Paper



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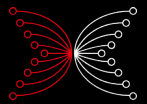
Highlevel Implementation



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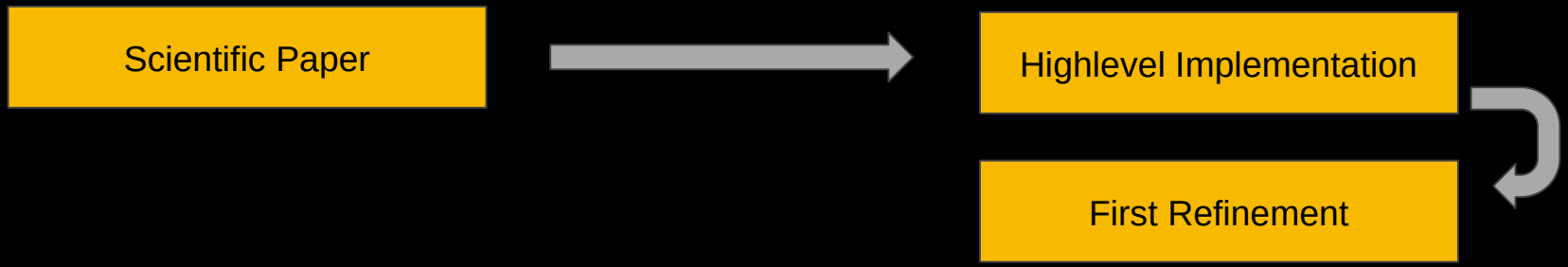

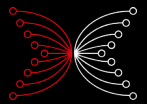

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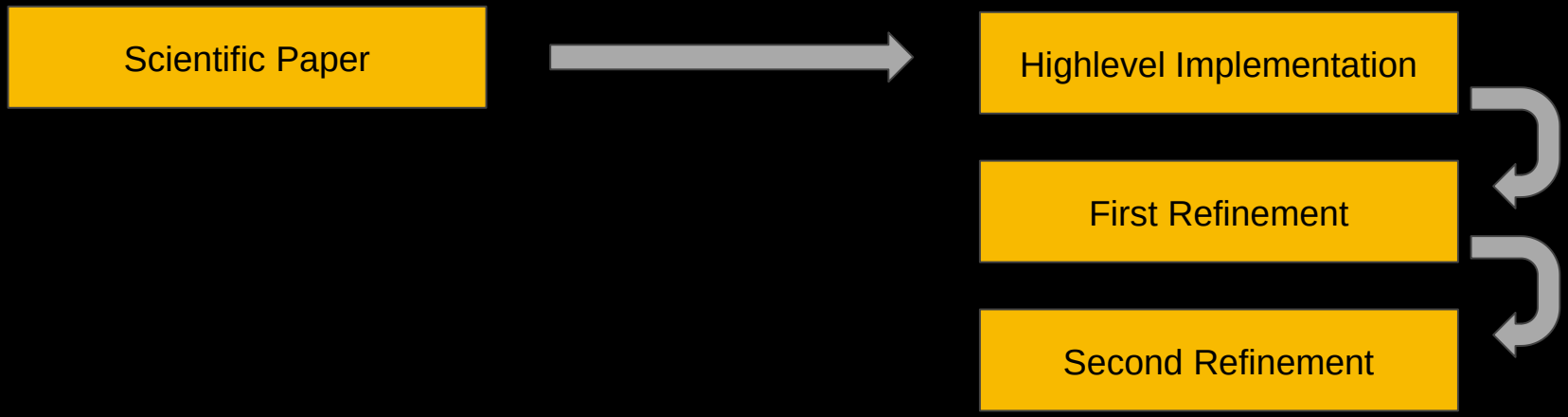

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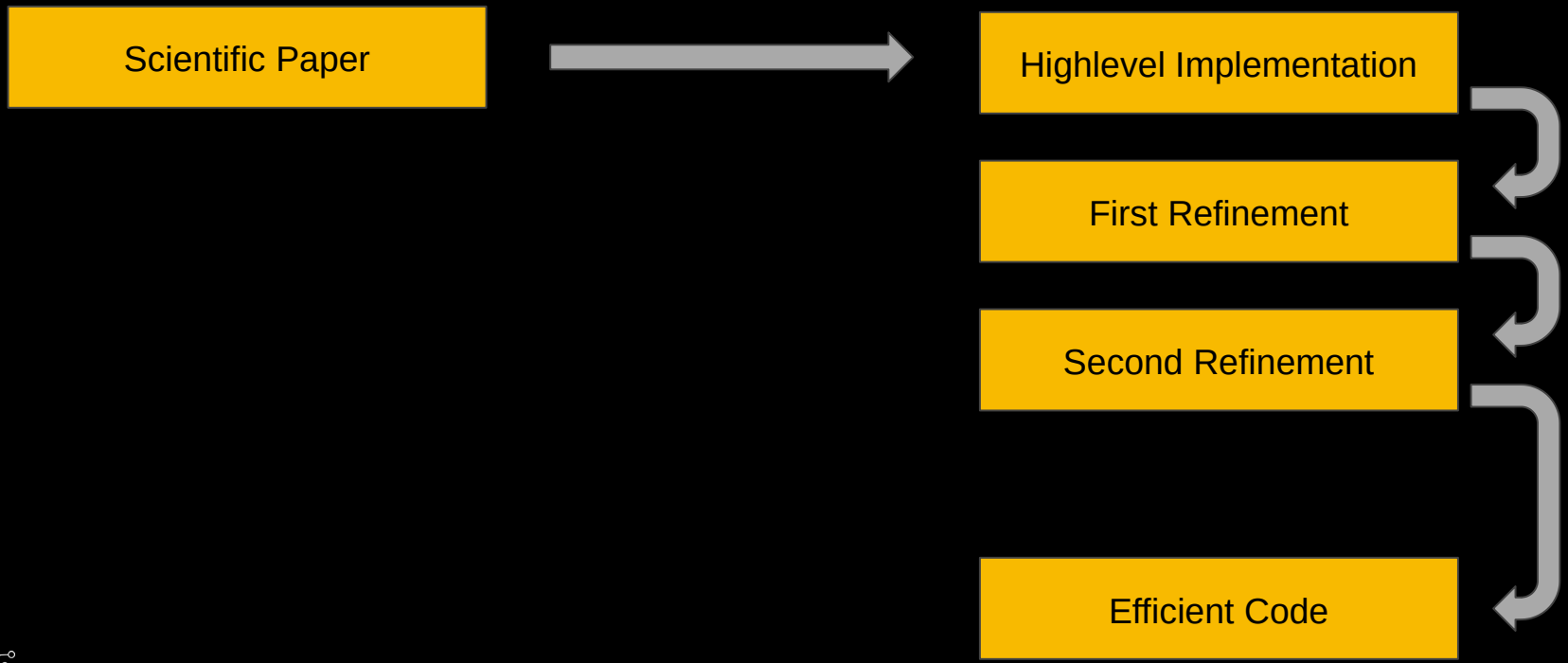

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Scientific Paper

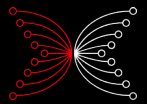
Highlevel Implementation

First Refinement

Second Refinement

Efficient Code

- “Implement” paper in high-level language (“Chi Calculus”).



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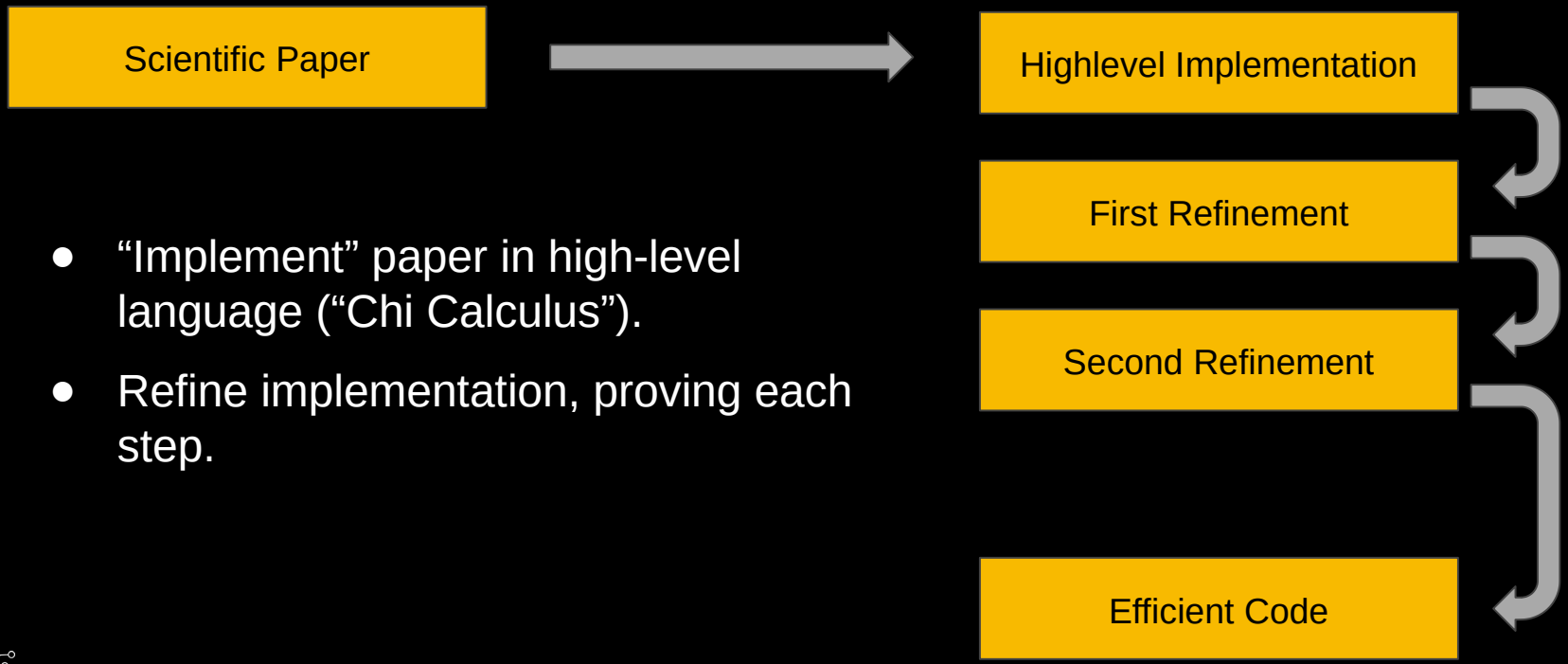

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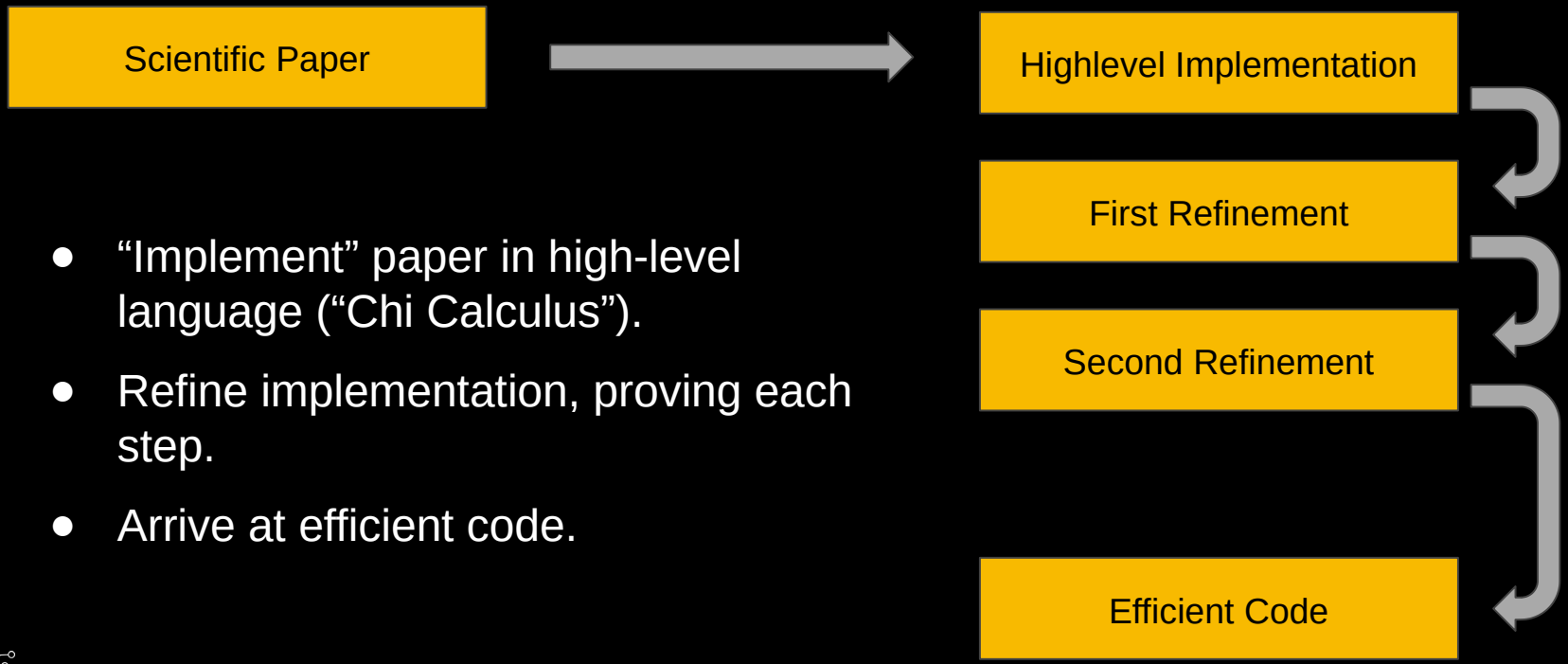

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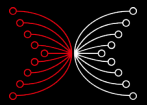
Chi Calculus



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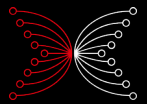

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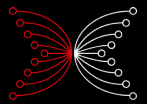

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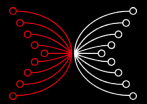

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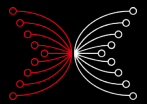

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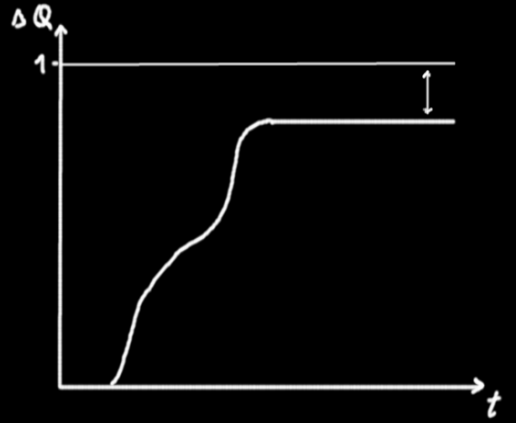
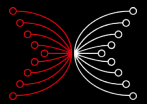
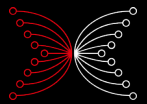
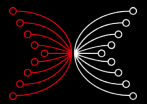




Incentives



The people doing all the hard work...



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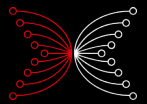

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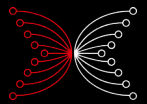

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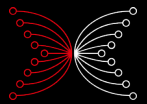

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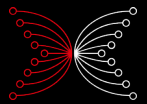
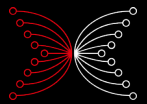
- In the case of Cardano, it means being online and creating a block when they have been elected slot leader and to participate in the election process.



(Non-)Monetary Incentives



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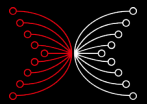

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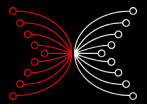

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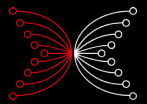
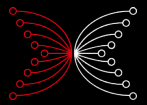
- **Ideally, monetary and moral incentives should align perfectly.**



Incentives in Cardano



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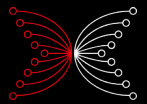

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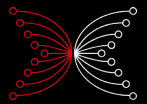

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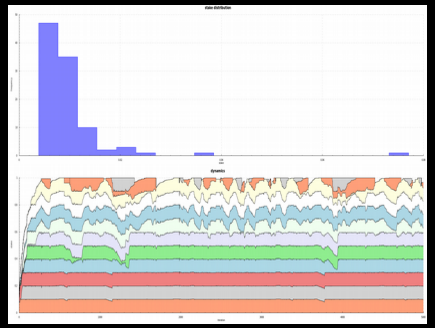
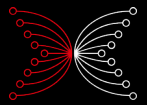
- In Cardano, we strive for perfect alignment of incentives.
- We use Game Theory and Simulations to develop and test our model.



Smart Contracts



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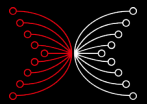

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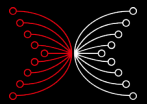

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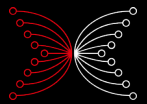

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- IELE Testnet: https://testnet.iohkdev.io/iele/

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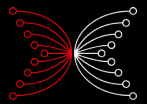

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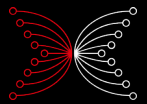
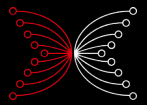


Ouroboros BFT



Ouroboros BFT

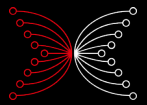
Ouroboros-BFT: A Simple Byzantine Fault Tolerant Consensus Protocol

Aggelos Kiayias* Alexander Russell†

September 7, 2018

Abstract

We present a very simple deterministic BFT protocol for ledger consensus. The protocol is executed by n servers over a synchronous network and can tolerate any number t of Byzantine faults with $t < n/3$. Furthermore, it enjoys instant confirmation: the client can obtain an assurance that a submitted transaction will be settled in a single round-trip time. A derivative, equally simple, binary consensus protocol is also presented. We also analyze the protcol in case of network splits and temporary loss of synchrony arguing the safety of the protocol when synchrony is restored. Finally, we examine the covert adversarial model showing that Byzantine resilience is increased to $t < n/2$.



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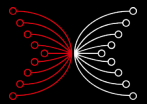

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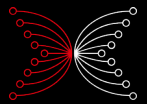

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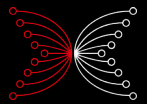

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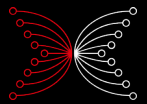
- Extremely expressive type system.



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- Questions?
- Comments?