Privacy in Bitcoin

On the Effectiveness of Clustering

Jonas Nick

March 15, 2016

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  - Privacy and fungibility essential characteristics of money.
- What?
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- This talk: There's a long road road ahead

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- *Clustering*: Given public key, use blockchain to find public keys owned by the same entity.

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In blockchain:

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Clustering reveals both addresses are from same wallet

Transactions

- balance-based vs. UTXO model

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Alice	2
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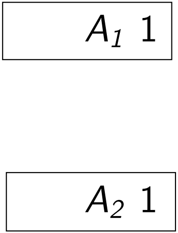
  - Transaction: `Alice` $\xrightarrow{\text{1 coin}}$ `Bob`
  - new Blockchain state

Alice	1
Bob	1

Transactions

- UTXOs (Unspent Transaction Outputs)
- Bitcoin's model



A_1 1

A_2 1

- Balance implicit
- Cash analogy

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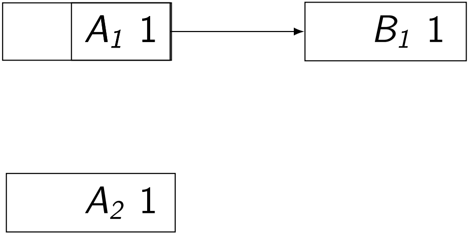

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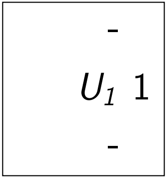

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- user U, merchant M
- spend tx *outputs* (value and recipient)

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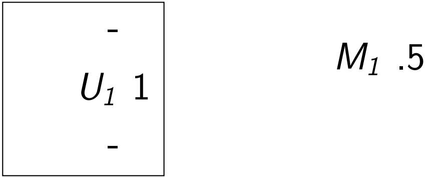

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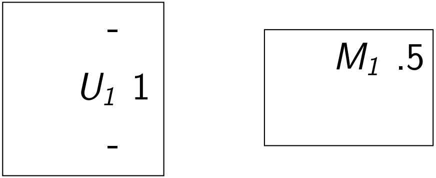

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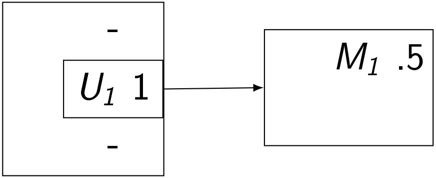

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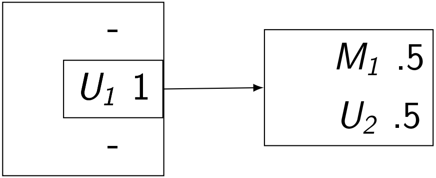

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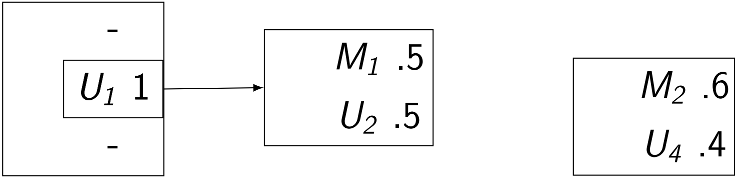

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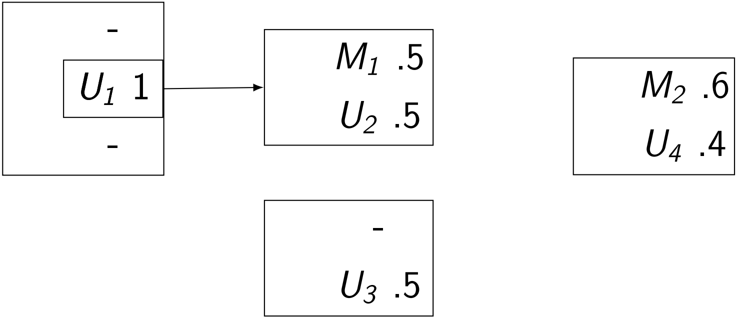

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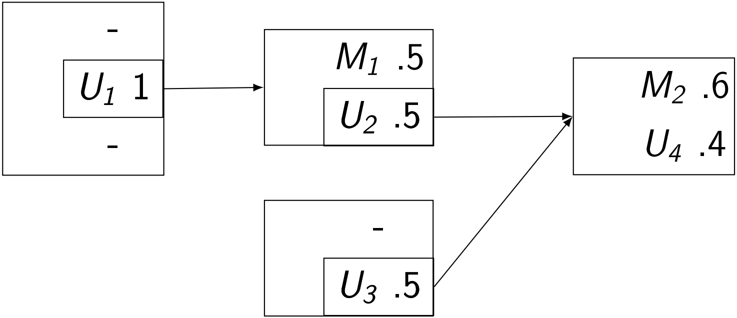

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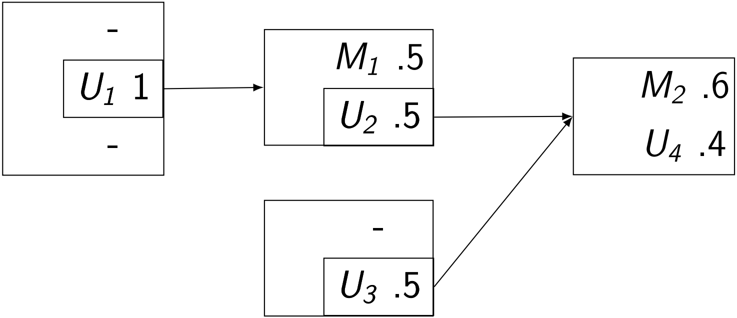

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- spend tx *outputs* (value and recipient)
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- *change*
- *multi-input tx*
- *pay-to-pubkey-hash*

Questions?

Clustering Strategies

- Given pubkey, use blockchain to find pubkeys of the same wallet
- make assumptions about wallet behavior
    - heuristics

Multi-input heuristic

All inputs of a transaction belong to the same wallet.

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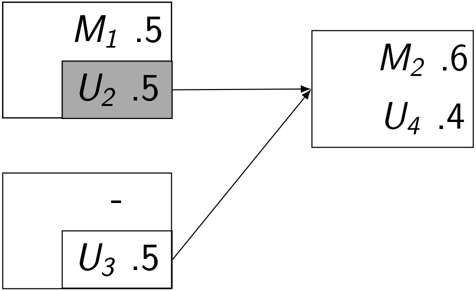

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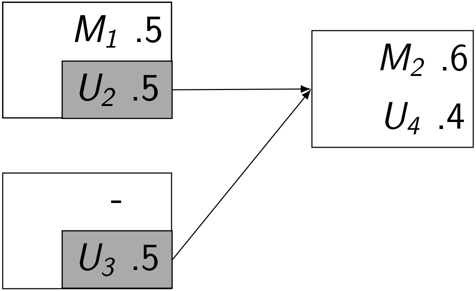

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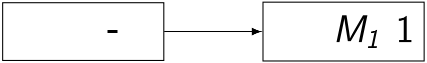

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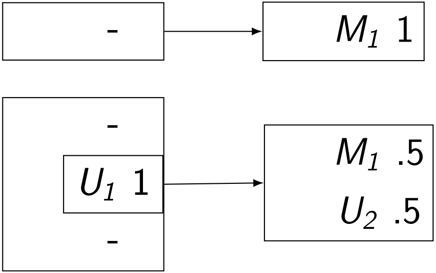

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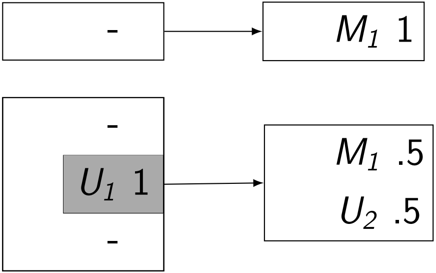

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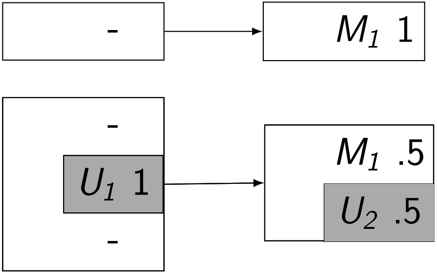

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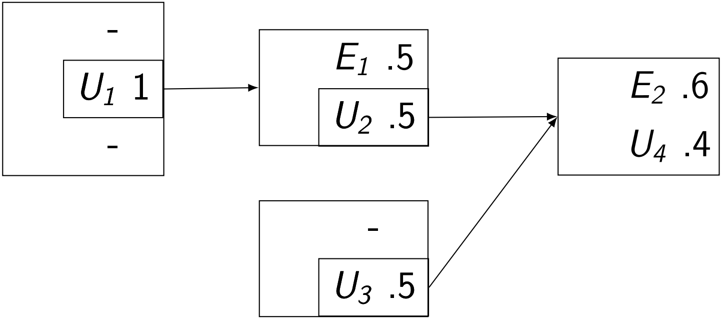

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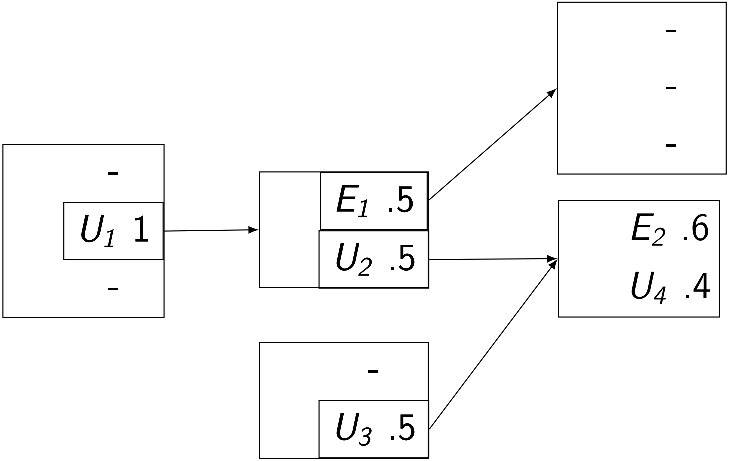

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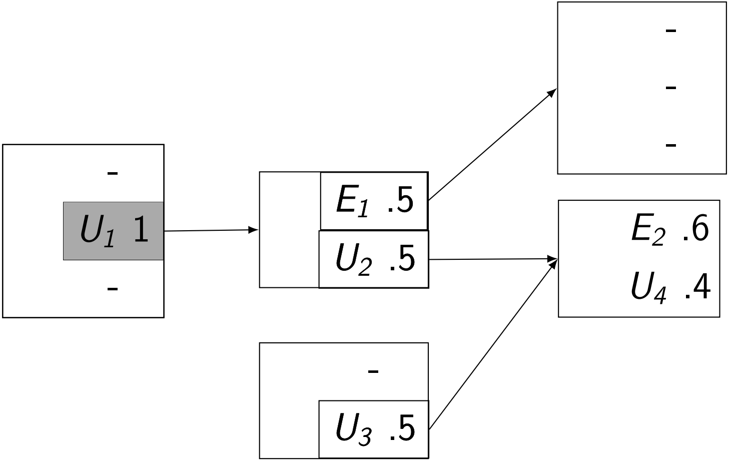

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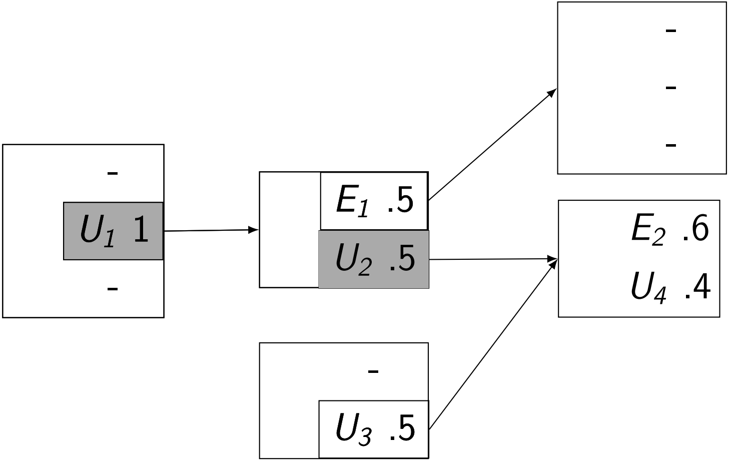

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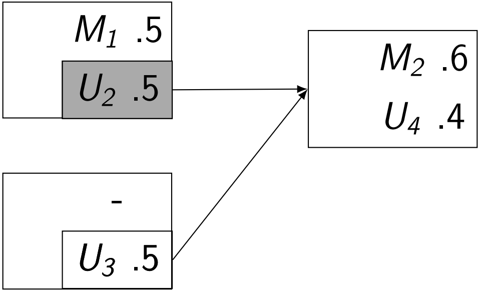

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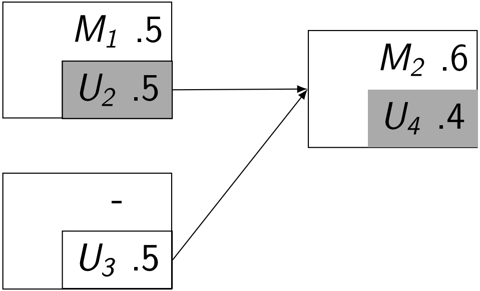

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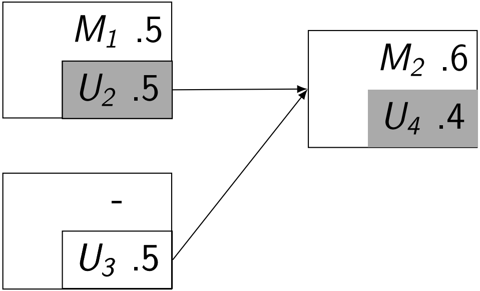

If there is a unique output with a value smaller than any of the inputs, then this is the change.

Next steps

- How to quantify privacy on the blockchain?
- Requires data...

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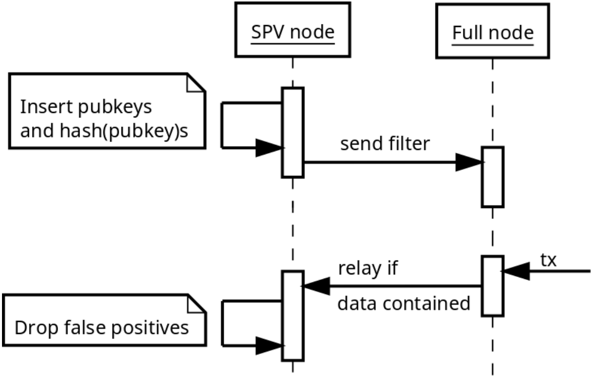
Bloom Filter in Bitcoin



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  - $=$ fp-rate^2
- most wallets: 1 false positive
- 20 crawlers collected 37,585 filters
- need to be picked up by seed nodes

Results

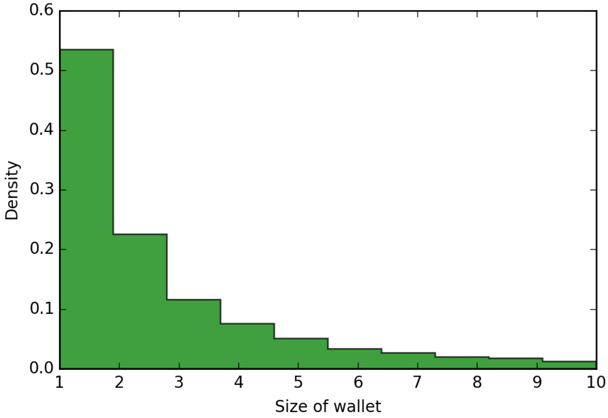

Figure Distribution of the number of pubkeys in captured BIP37 wallets.

Results

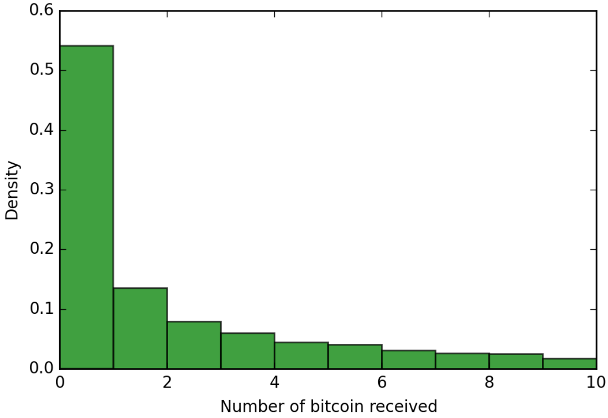

Figure Distribution of total received bitcoins for a subset of wallets.

Mitigation

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- Alternatives
  - a central server that learns all of the client's addresses
  - full node

Evaluate Clustering

- Collected filters allow to reconstruct all pubkeys of a wallet
- Can apply clustering and evaluate clustering performance using ”Ground truth”

Performance metric

- precision: $\Pr(\text{in wallet}|\text{heuristic})$
- recall: $\Pr(\text{heuristic}|\text{in wallet})$

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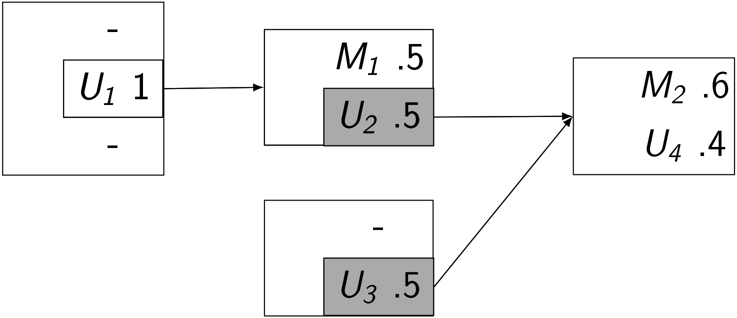
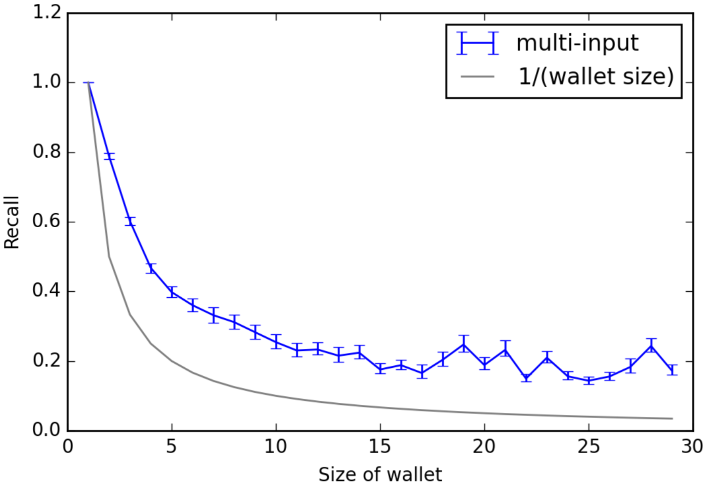


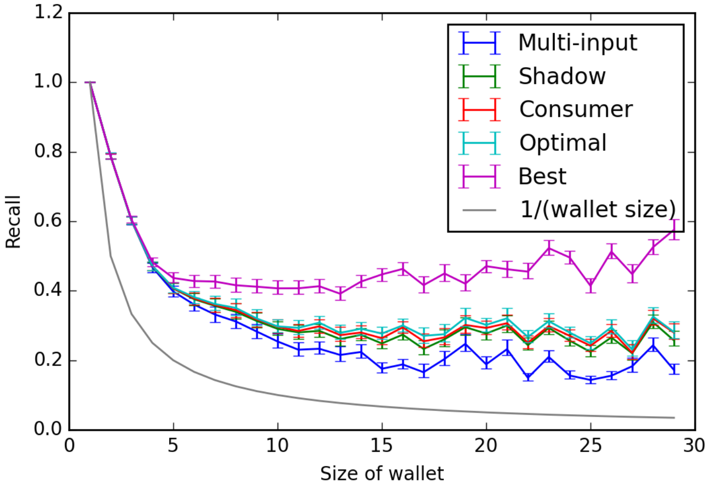
precision: 1, recall: $\frac{2}{4}$

Results

Heuristic	mean recall
1/(wallet size)	66.27%
Multi-input	68.59%
Shadow	69.16%
Consumer	69.26%
Optimal	69.34%
Best	70.94%


multi-input
1/(wallet size)
Recall
Size of wallet
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
5
10
15
20
25
30

Result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- introduced two new clustering strategies
- evaluated performance of clustering using ground truth
- modern wallets: 70% recall

Countermeasures for User

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- altcoins?

Countermeasures for Developer

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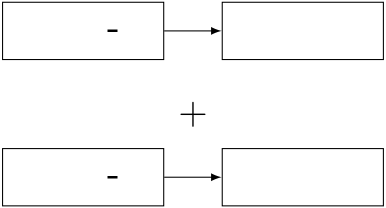

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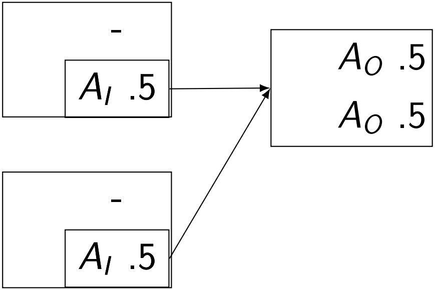

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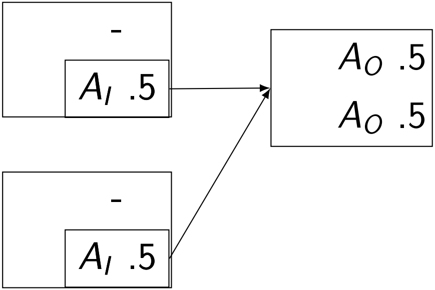
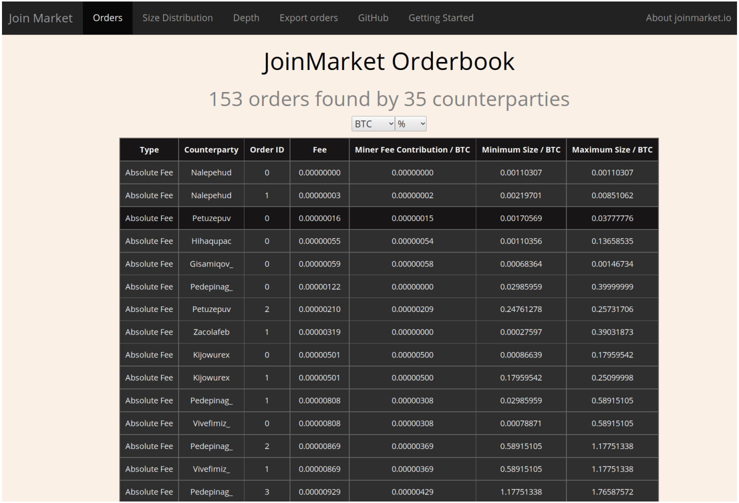


  - trustless, but
  - UI, exact protocol challenging
  - Confidential transactions

Countermeasures for User

- Joinmarket



JoinMarket Orderbook

153 orders found by 35 counterparties

BTC %

Type	Counterparty	Order ID	Fee	Miner Fee Contribution / BTC	Minimum Size / BTC	Maximum Size / BTC
Absolute Fee	Nalepehud	0	0.00000000	0.00000000	0.00110307	0.00110307
Absolute Fee	Nalepehud	1	0.00000003	0.00000002	0.00219701	0.00851062
Absolute Fee	Petuzepuv	0	0.00000016	0.00000015	0.00170569	0.03777776
Absolute Fee	Hihaqupac	0	0.00000055	0.00000054	0.00110356	0.13658535
Absolute Fee	Gisamiqov_	0	0.00000059	0.00000058	0.00068364	0.00146734
Absolute Fee	Pedepinag_	0	0.00000122	0.00000000	0.02985959	0.39999999
Absolute Fee	Petuzepuv	2	0.00000210	0.00000209	0.24761278	0.25731706
Absolute Fee	Zacolafeb	1	0.00000319	0.00000000	0.00027597	0.39031873
Absolute Fee	Kijowurex	0	0.00000501	0.00000500	0.00086639	0.17959542
Absolute Fee	Kijowurex	1	0.00000501	0.00000500	0.17959542	0.25099998
Absolute Fee	Pedepinag_	1	0.00000808	0.00000308	0.02985959	0.58915105
Absolute Fee	Vivefimiz_	0	0.00000808	0.00000308	0.00078871	0.58915105
Absolute Fee	Pedepinag_	2	0.00000869	0.00000369	0.58915105	1.17751338
Absolute Fee	Vivefimiz_	1	0.00000869	0.00000369	0.58915105	1.17751338
Absolute Fee	Pedepinag_	3	0.00000929	0.00000429	1.17751338	1.76587572

Q&A

- Questions?
- Contact
  - nickler.ninja
    - slides: nickler.ninja/slides/2016-zurich-meetup.pdf
    - thesis: nickler.ninja/papers/thesis.pdf
  - jonas@blockstream.com