FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

Diplomarbeitspräsentation

ALGORITHMS AND COMPLEXITY GROUP

Monero Cross-Chain Traceability

Empirical Analysis of Privacy Implications from Currency Hard-Forks

Masterstudium:

Computational Intelligence

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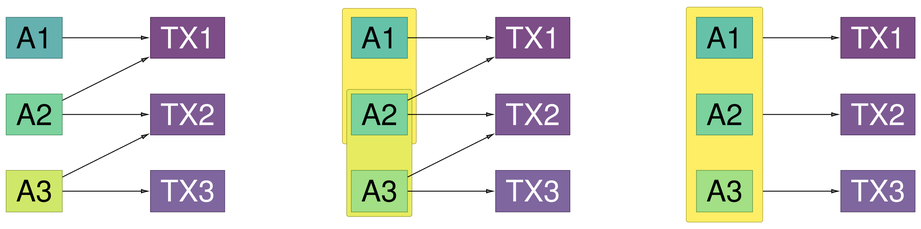
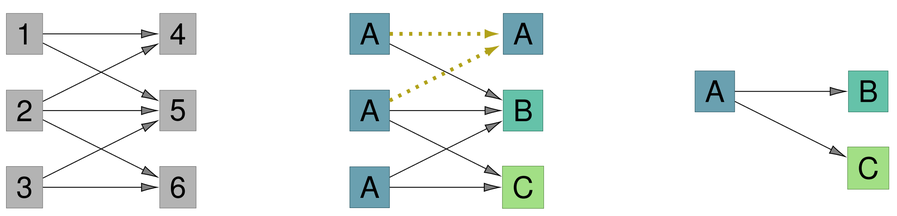
Motivation

- Several methods to analyze Bitcoin transactions history
  - Multi-Input heuristic clusters addresses (A1-A3) of inputs occuring in single transaction (TX) as they likely belong to the same user



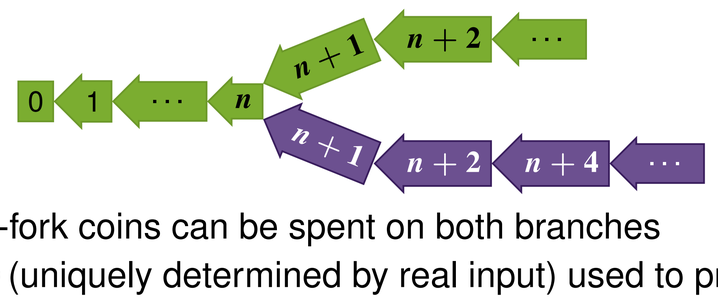
  - Address-graph (left) labelled with address-clusters from multi-input heuristic (center) can be simplified to entity-graph (right)



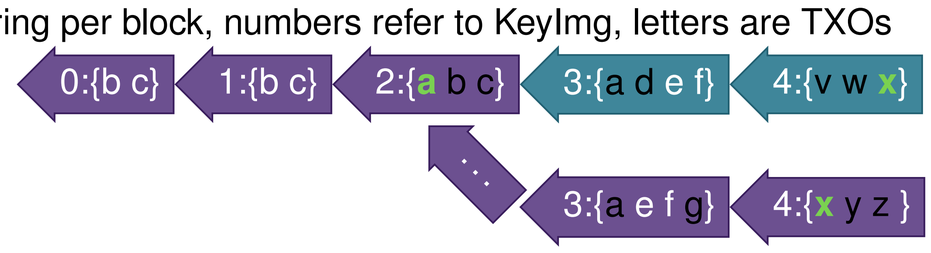
- Increased chance of users being identified via TX-history
- $\Rightarrow$ privacy-centric coins, e.g. Monero, based on CryptoNote [3]
- Features of Monero, privacy-coin with highest market-cap:
  - **Unlinkability:** *Stealth addresses* hide recipients of transactions
  - **Untraceability:** Each TX input is a ring instead of a TXO (TX output). A ring is a set of TXOs (with the same denomination), one of which is the real input and the others are decoys (*mixins*). These *ring signatures* obfuscates the path of a given coin.
  - **Fungibility:** Values of TXOs are hidden with RingCT (confidential TXs) since 2017, making denomination constraint of rings unnecessary.
- Analysis methods from other currencies do not work for Monero

Forks & Cross Chain Analysis (CCA)

- Cryptocurrencies forks result in two coins with a common history



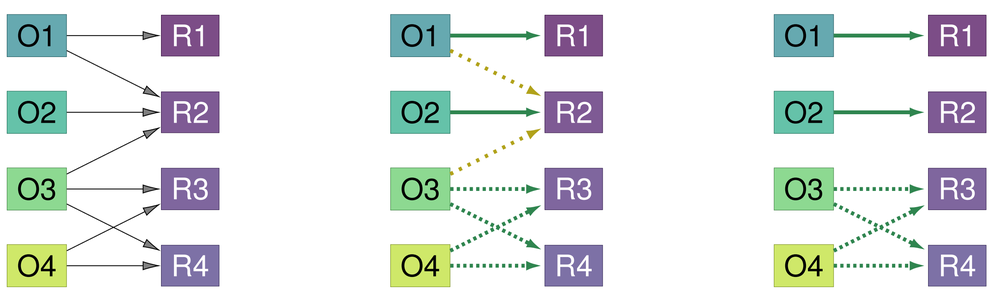
- Unspent pre-fork coins can be spent on both branches
- A *key image* (uniquely determined by real input) used to prevent double spending
- If multiple rings (one per branch) have the same KeyImg, the same pre-fork TXO is spent in them
- Real input is in intersection of the rings
- TXOs in the symmetric difference must be decoys
- Monero blockchain (XMR) two blocks before and after a fork (XMO)
- One ring per block, numbers refer to KeyImg, letters are TXOs



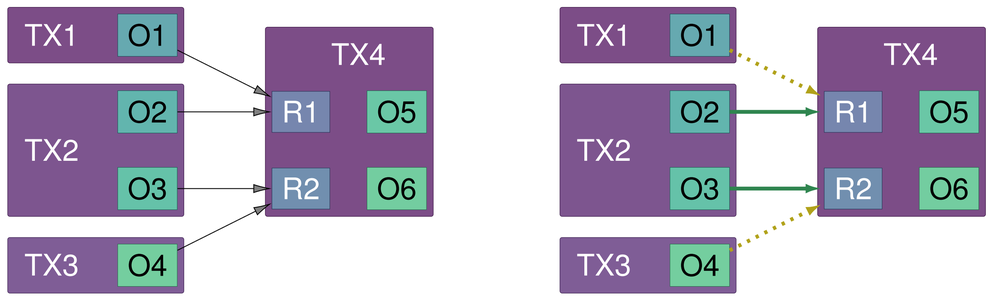
1. IR can be applied to ring 0 and 1, b, c therefore decoys in ring 2.
2. ZMR sets a as **real input** in ring 2 and decoy in both rings 3.
3. CCA sets d, g as decoys because $\notin \{a,d,e,f\} \cap \{a,e,f,g\}$
4. CCA sets x as real input because $|\{v,w,x\} \cap \{x,y,z\}| = 1$

Traceability Analysis

- Two independent 2017 publications [1, 2] demonstrated that a majority of transactions are traceable. They used the following deductions techniques and heuristics:
  - Zero Mixin & Intersection Removal (ZMR & IR): Ring R1 has only one referenced TXO (O1), which is therefore the real input ( ) in that ring and all occurrences in other rings (R2) have to be decoys ( ) and can thus be removed. Intersection removal is a generalization of this technique that marks TXOs occoring in n rings (R3,R4) with n identical members (O3,O4) as spent ( ).



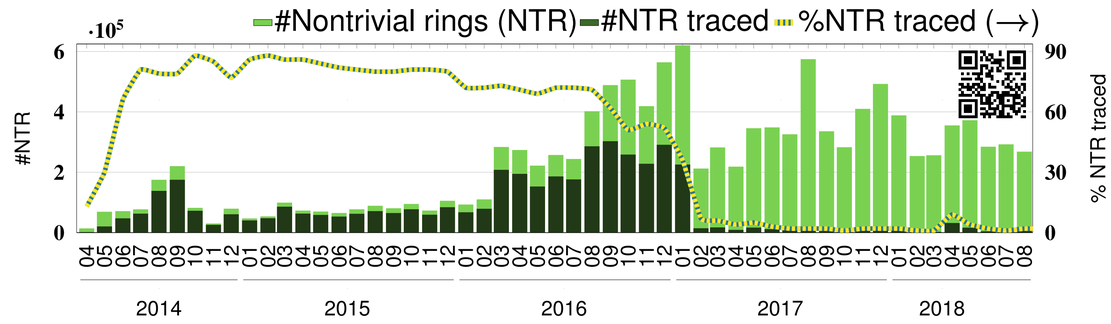
  - Guess Newest Heuristic (GNH): Exploits naive decoy sampling. As time distribution of decoys and real outputs differed, most recent TXO was real input in most cases.
  - Output Merging Heuristic (OMH): TX4 merges multiple TXOs (O2,O3) from TX2 in distinct rings (R1,R2). OMH assumes that those are the real inputs.



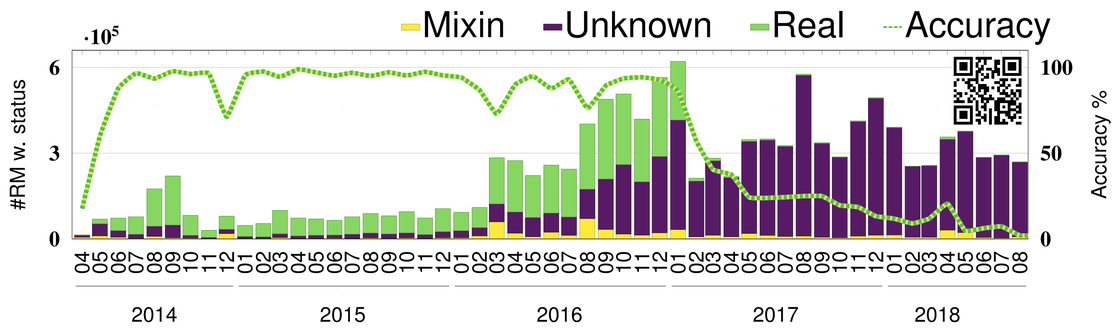
- Monero developers reacted by implementing countermeasures:
  - Higher mandatory minimum ringsize against ZMR (from 3 to 7)
  - Improved decoy sampling against GNH (sampling multiple $\leq$1.8 day old inputs and soon from a γ-distribution)
- This work contributes to the state of the art in two ways:
  - We propose a new tracing method, which exploits information leaked on currency-forks. We measure the privacy-impact from two recent forks (Monero Original & MoneroV)
  - We evaluate the accuracy of GNH & OMH based on results from our traceability analysis (using ZMR, IR and our new method).

Results

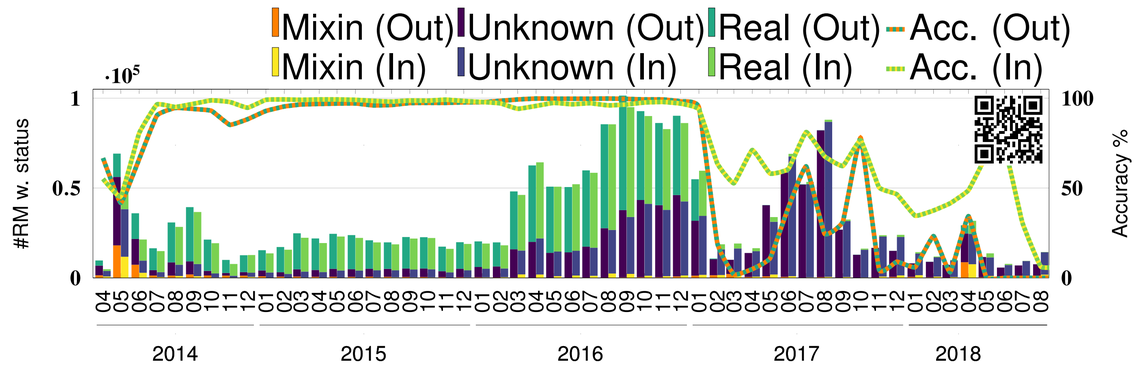
- Number of nontrivial rings (NTR, > 1 RM)) and traced NTRs.
  - Accuracy low since 2017/RingCT. Small peak in April 2018 due to CCA.



- Status of RM identified as 'real' with GNH and OMH.
  - Improved decoy sampling routines resulted in low accuracy.



  - Aggregation by output-creation (out) or spend time (in).
  - Lower # of applications due to less outputs/inputs since RingCT.



- Results suggest that amount of traceable rings with current transaction protocol is low enough to not jeopardize privacy of Monero's users.
- Forks with more traction than XMO/XMV could have higher impact.

[1] Amrit Kumar et al. A traceability analysis of Monero's blockchain. In *European Symposium on Research in Comp. Sec.*, pages 153–173. Springer, 2017.
[2] Malte Möser et al. An Empirical Analysis of Traceability in the Monero Blockchain. *PoPET*, 2018(3):143–163, June 2018.
[3] Nicolas Van Saberhagen. Cryptonote v 2. 0. `https://cryptonote.org/whitepaper.pdf`, 2013.

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