An Empirical Analysis of Monero Cross-Chain Traceability

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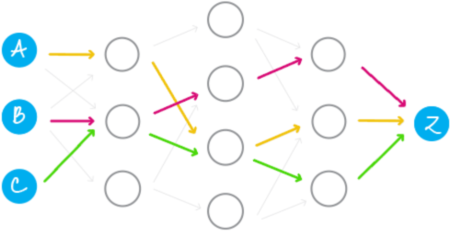

Source: `https://cryptonote.org/inside/`

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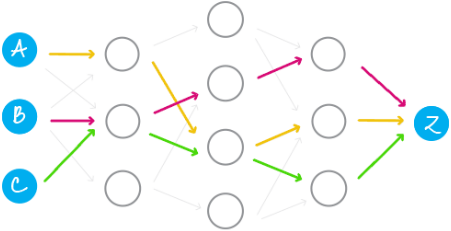

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- Decoys are sampled from set of eligible outputs

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    - temporal distribution of mixins and real spending behavior didn’t match - most recent input often the real one

Improvements to the protocol

- ZMR works like a chain reaction from an initial set of inputs without decoys.
  - Since 2016, the mandatory minimum ringsize has been increased
  - Minimum ringsizes + RingCT TX were effective
  - Ringsize $\equiv 11$ since last update
- Mixin sampling has been improved with different approaches
  - Triangular distribution
  - Recent zone: Force 25-50% recent outputs
  - Gamma distribution: Distribution based on empirical analysis

Contribution of this work

- Reevaluation of existing methods
  - Previous studies published shortly after introduction of RingCT
  - Changes to mixin sampling and ringsize in 09/2017 and 04/2018.
- Quantification of impact due to recent (Spring 2018) Monero hardforks
  - Monero Original: Continuation of Monero v6 (ASIC compatible)
  - MoneroV: Fork with some changes to emission curve

Currency hardforks

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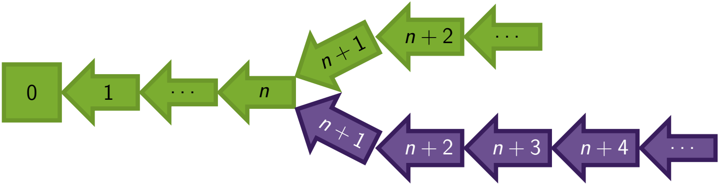

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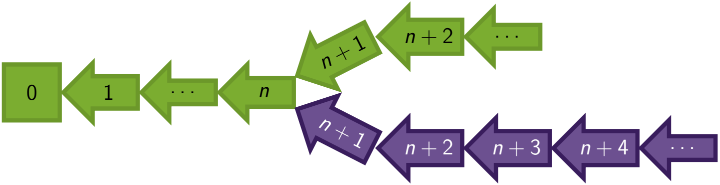

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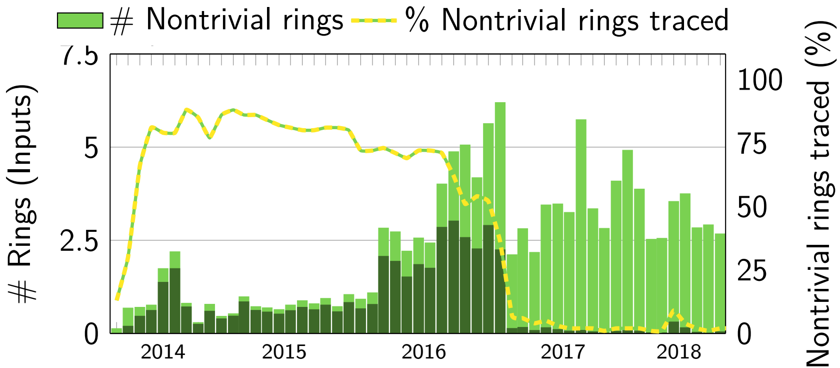
- Monero prevents double spends with *key images* (unique identifier derived from spent output)
- If two rings on separate branches share a key image, they spend the same output.

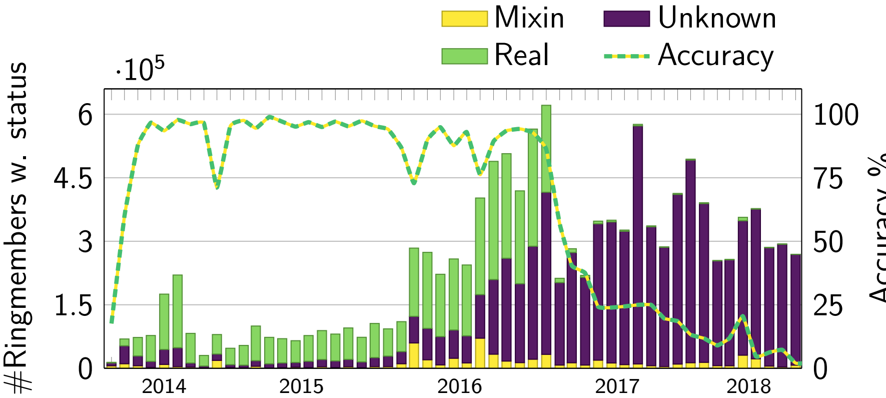
Dataset & Method

1. Exported Monero (XMR), MoneroV (XMV) and Monero Original (XMO) blockchain up to Aug. 31$^{\text{th}}$, 2018.
2. Employed Zero Mixin Removal & Intersection Removal
3. Added fork data and applied cross chain analysis (+ZMR/IR)
4. Applied heuristics from [Kumar et al., 2017] and [Möser et al., 2018]:
   - Guess Newest Heuristic
   - Output Merging Heuristic
5. Evaluated accuracy with ground truth (where possible) with results from steps 3 (OMH see paper).

Traced Inputs



Guess Newest Heuristic



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- Guess Newest Heuristic does not work with current mixin sampling technique
- Impact from Cross Chain Analysis not very large
  1. Forks so far didn't have a lot of traction (maybe disputes over ASICs change that)
  2. Mandatory ringsize of 7 enough to prevent chain reactions (11 is even better)

Data & source available:

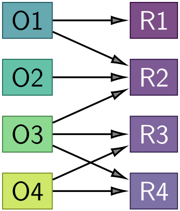
References

- Kumar, A. et al. (2017).
  A traceability analysis of Monero's blockchain.
  In *European Symposium on Research in Comp. Sec.*

- Möser, M. et al. (2018).
  An Empirical Analysis of Traceability in the Monero Blockchain.
  PoPET, 2018(3):143–163, DOI: 10.1515/popets-2018-0025.

- Van Saberhagen, N. (2013).
  Cryptonote v 2. 0.
  https://cryptonote.org/whitepaper.pdf.

Zero Mixin Removal & Intersection Removal



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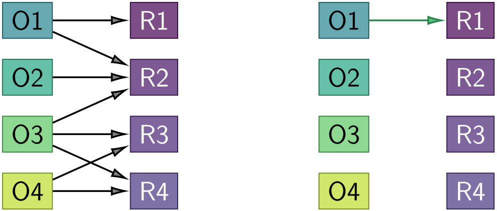

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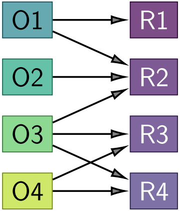

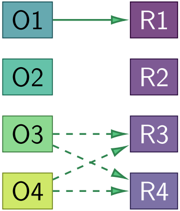

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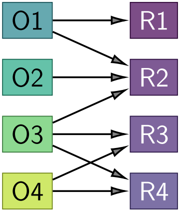

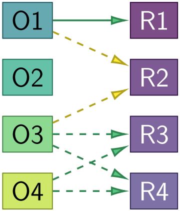

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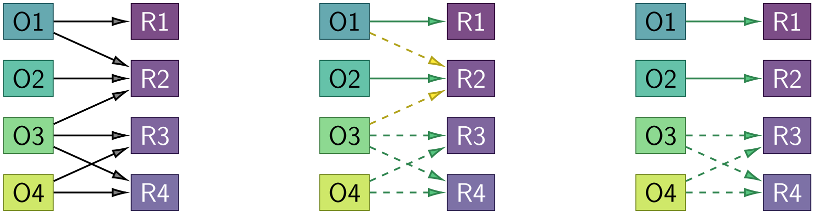

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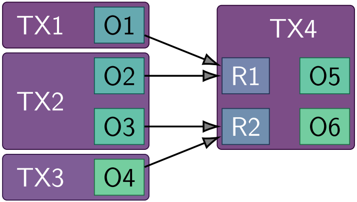

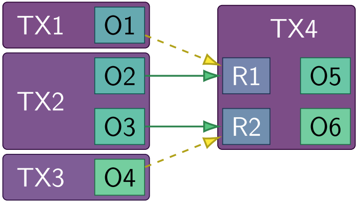

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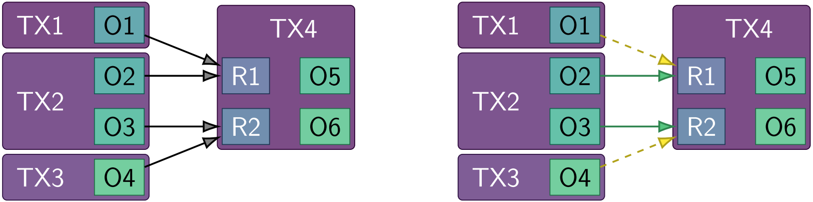
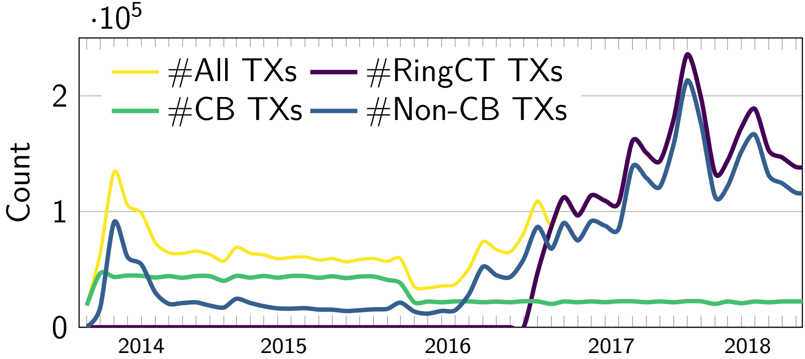
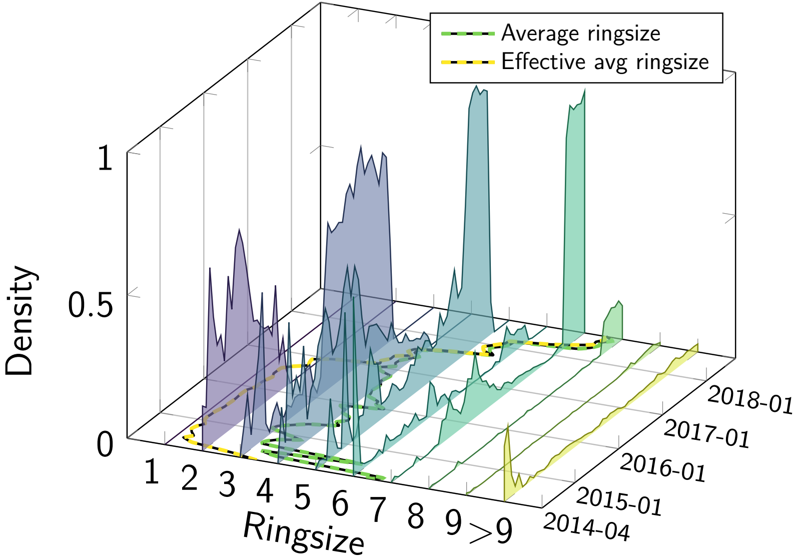


- TX4 has two inputs which reference a TXO from TX2
- OMH assumes that these outputs are real

Monero Activity




Average ringsize
Effective avg ringsize
Density
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0.5
0
Ringsize
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2017-01
2016-01
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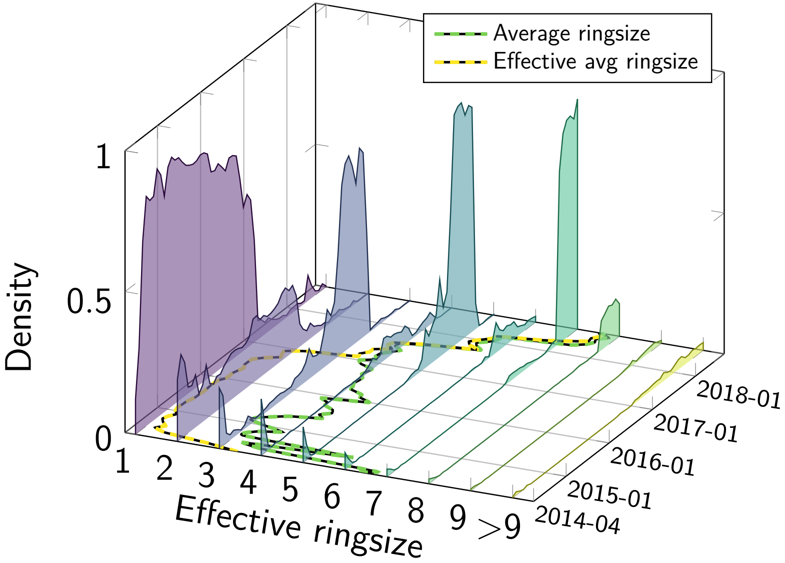
2014-04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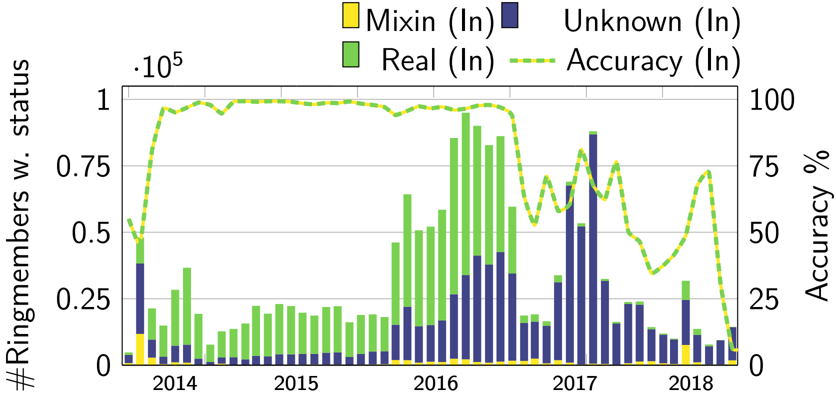
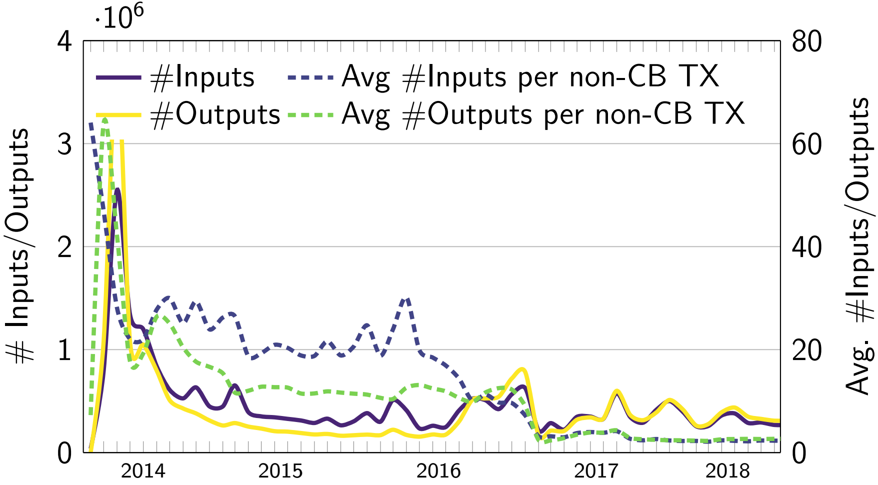


Inputs/Outputs (per TX)


·10^6
# Inputs/Outputs
Avg. #Inputs/Outputs
#Inputs
#Outputs
Avg #Inputs per non-CB TX
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