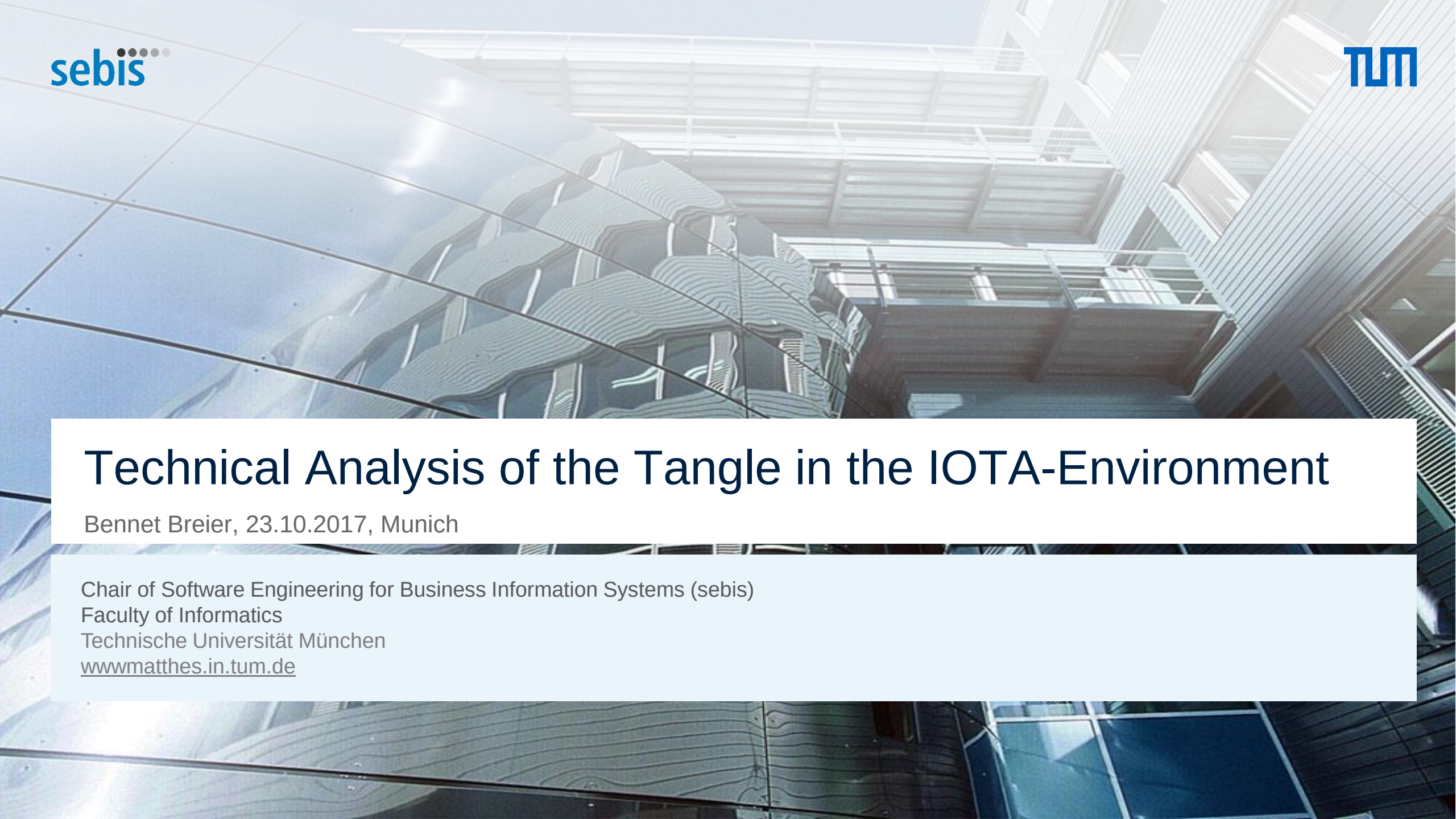

Technical Analysis of the Tangle in the IOTA-Environment

Bennet Breier, 23.10.2017, Munich

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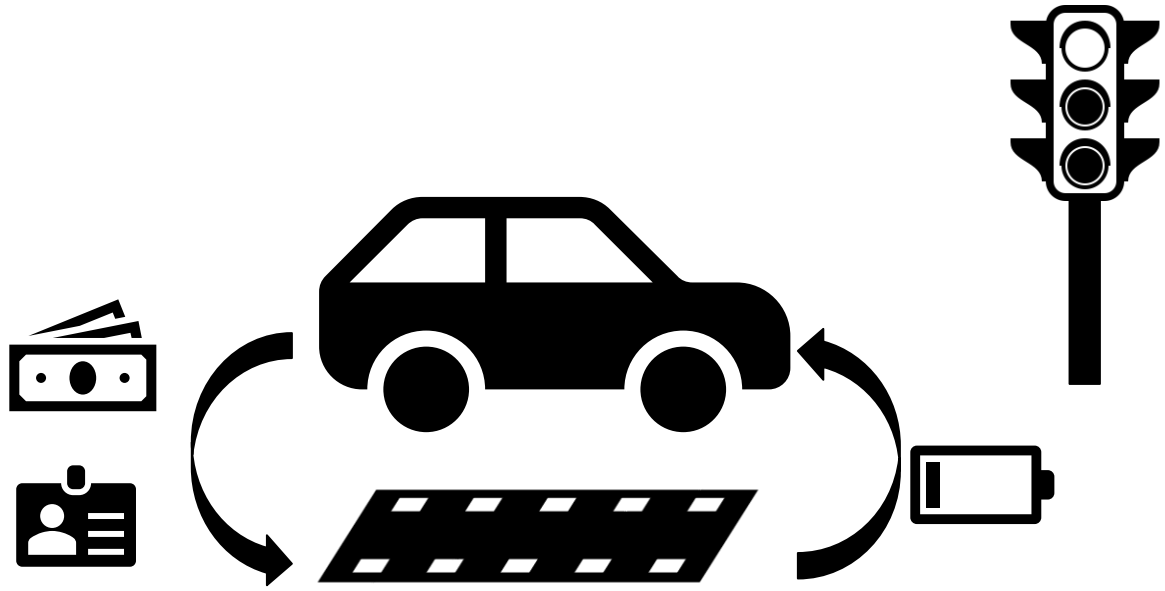
Outline

1. Motivation
2. Research Questions
3. Research Approach
4. Findings
    1. Analysis of the Tangle
    2. Comparison of Tangle & Blockchain
    3. The Tangle in the IOTA-environment
5. Conclusion & Outlook

Motivation

Inductive charging:

- ✓ Instant authentication
- ✓ Trustless Micro-payments
- ✓ Fast
- ✓ Scalable
- ✓ Immutable



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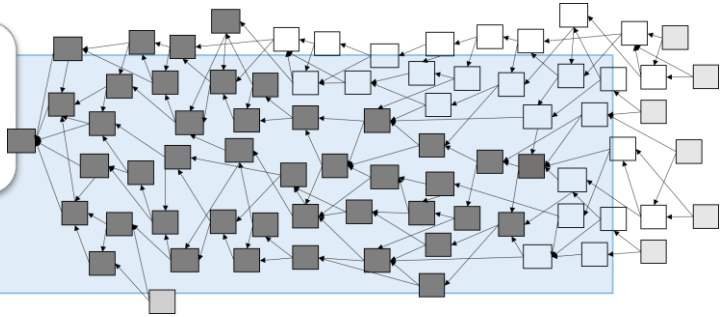
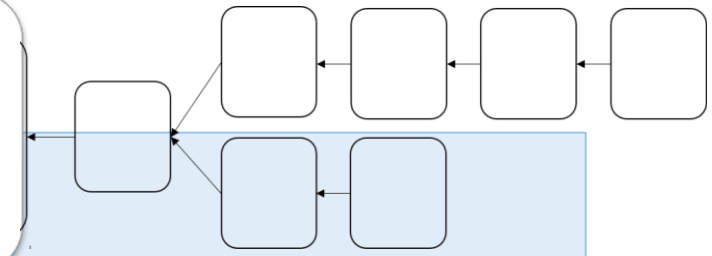
Research Questions

1. What is the theoretical foundation of the Tangle?



2. What are the key similarities & differences between Tangle and Blockchain?



3. How does IOTA use and advance the Tangle in its environment?

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Research Approach

✓ Literature & online research
(google scholar, Blog posts)

✓ Online-communities
- Slack team (incl. private messages)
- forum.iota.org
- reddit
- Github (+ code review)

✓ 2 interviews with members of IOTA:
- Paul Handy (core-developer)
- Alexander Renz (business advisor)

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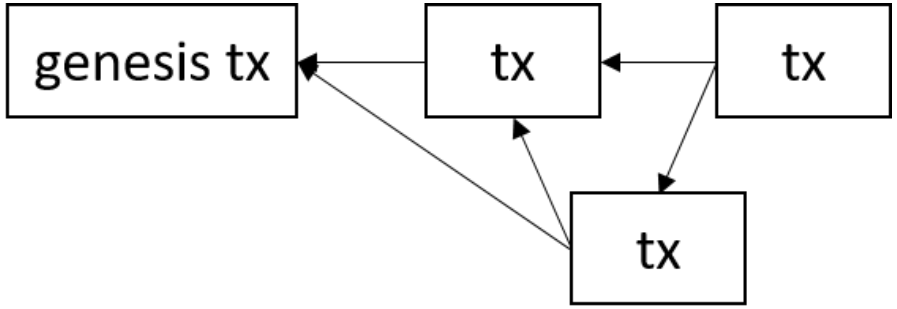
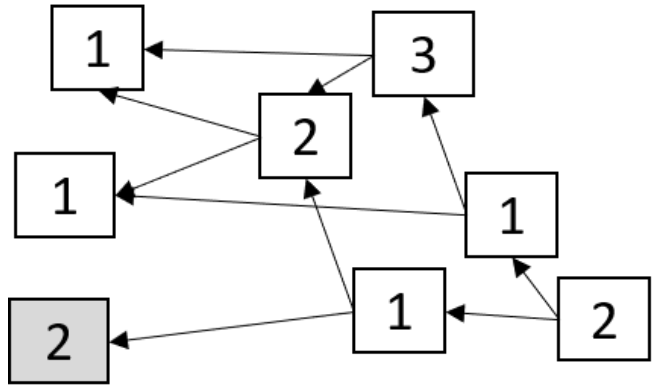
The Tangle

Initialization





Cumulative Weight = 5

The Tangle

Issuing a Transaction

1. Bundling & Signing
2. Tip Selection
3. Validation
4. Proof-of-Work (PoW)
5. Publishing

The Tangle

1. Bundling & Signing

Structure of a transaction

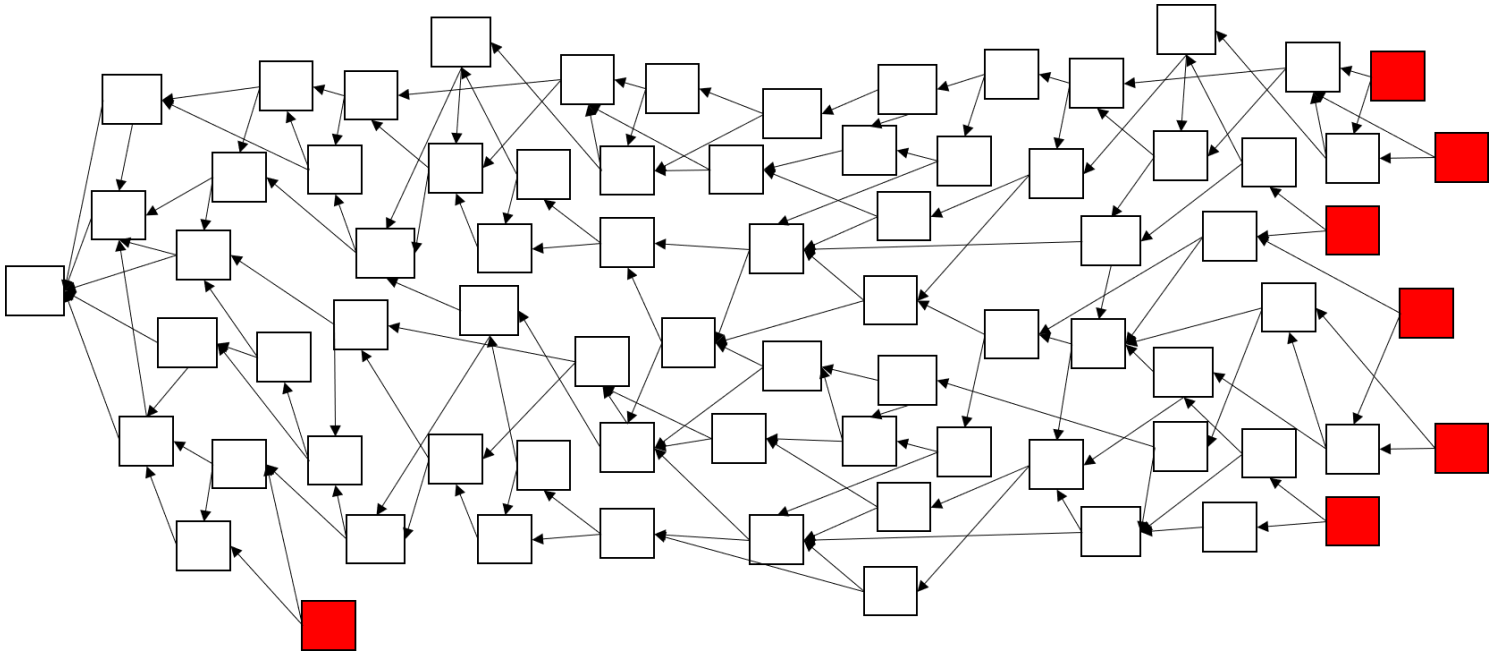
hash
signatureMessageFragment address value (timestamp)
currentIndex lastIndex bundle
trunkTransaction branchTransaction
nonce

tx_0	80 iota	output
tx_1	-100 iota	input
tx_2	0 iota	input
tx_3	20 iota	remainder

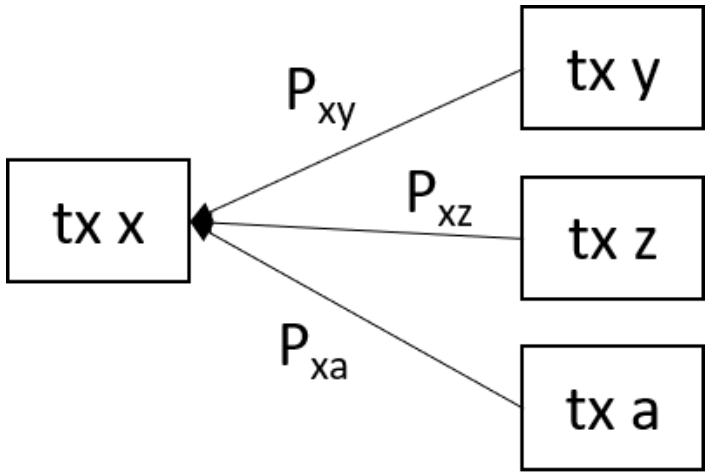
The Tangle

2. Tip Selection

Markov Chain Monte Carlo (MCMC)



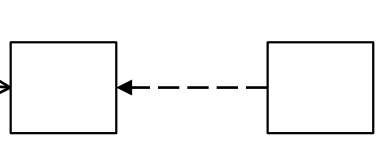
$$P_{xy} = \frac{e^{-\alpha(H_x - H_y)}}{\sum_{z:x \leftsquigarrow z} e^{-\alpha(H_x - H_y)}}$$



The Tangle

3. Validation

1. valid sub-tangle
   valid sub-tangle
   valid sub-tangle



+

2. Check PoW

+

3. all address-balances >= 0

no temporal order!

$$A \rightarrow B\ (10)$$
$$B \rightarrow C\ (10)$$

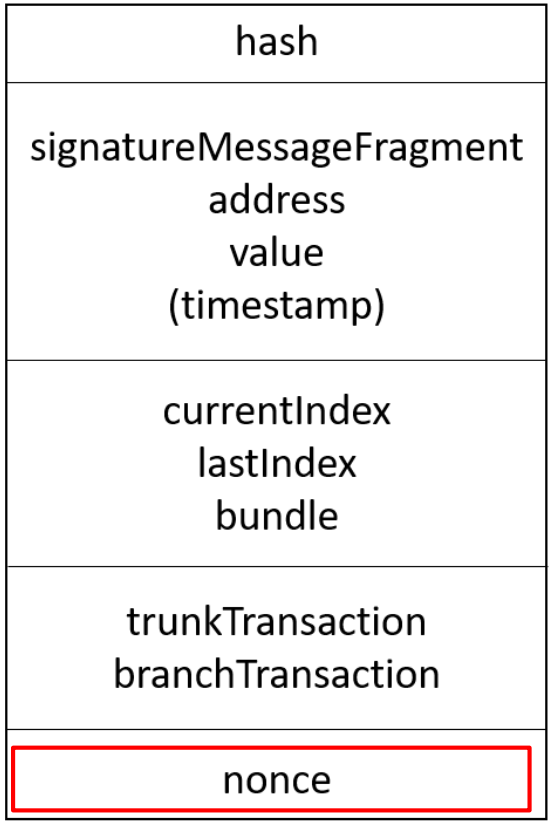
The Tangle

4. PoW

Hashcash

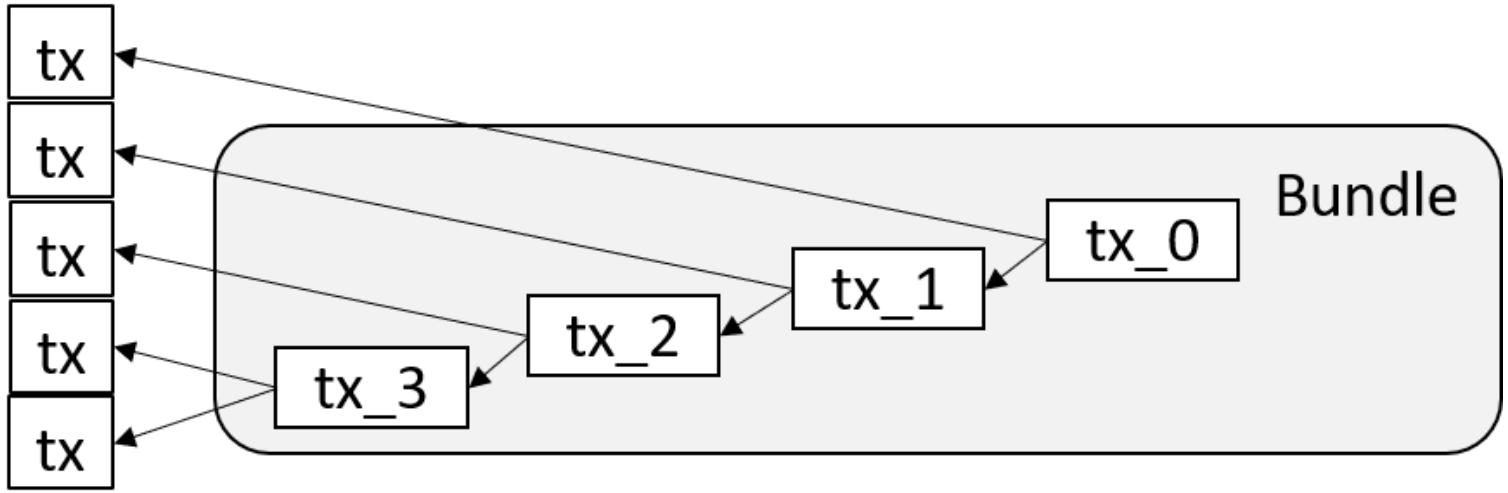
- ✓ DDOS-protection
- ✓ Immutability
- ✓ Protection against double-spending

Structure of a transaction



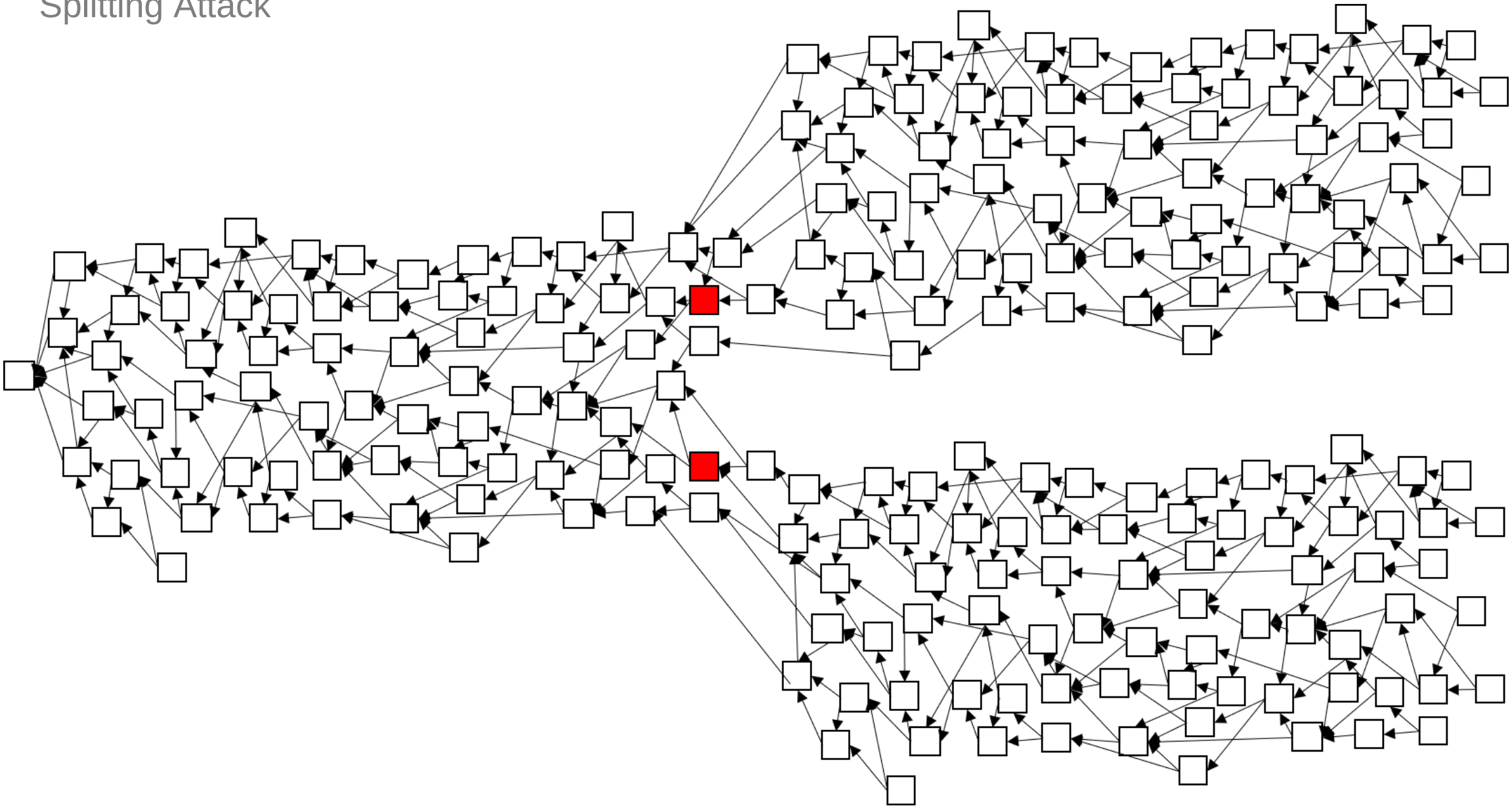
The Tangle

5. Publishing



The Tangle

Splitting Attack



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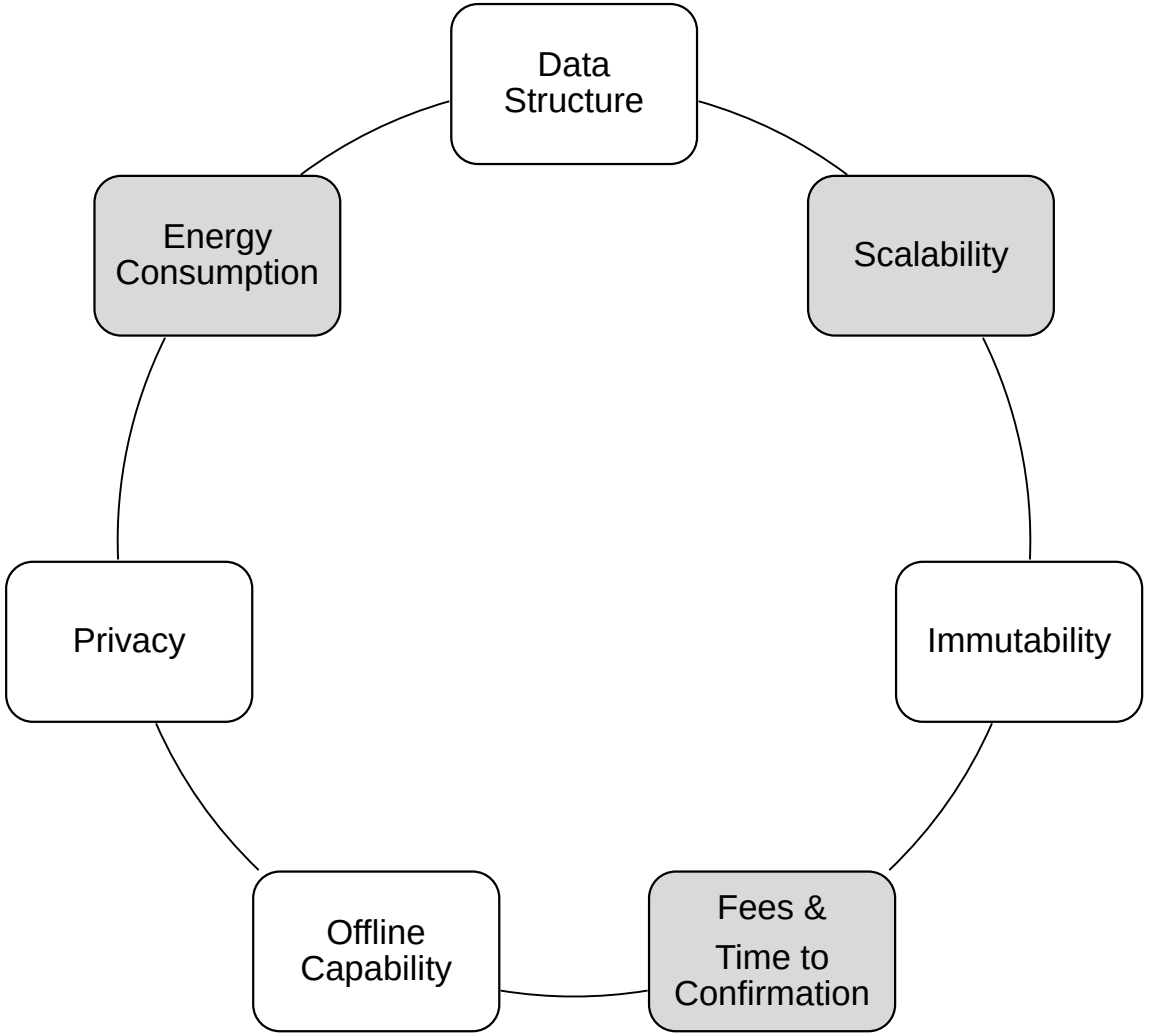
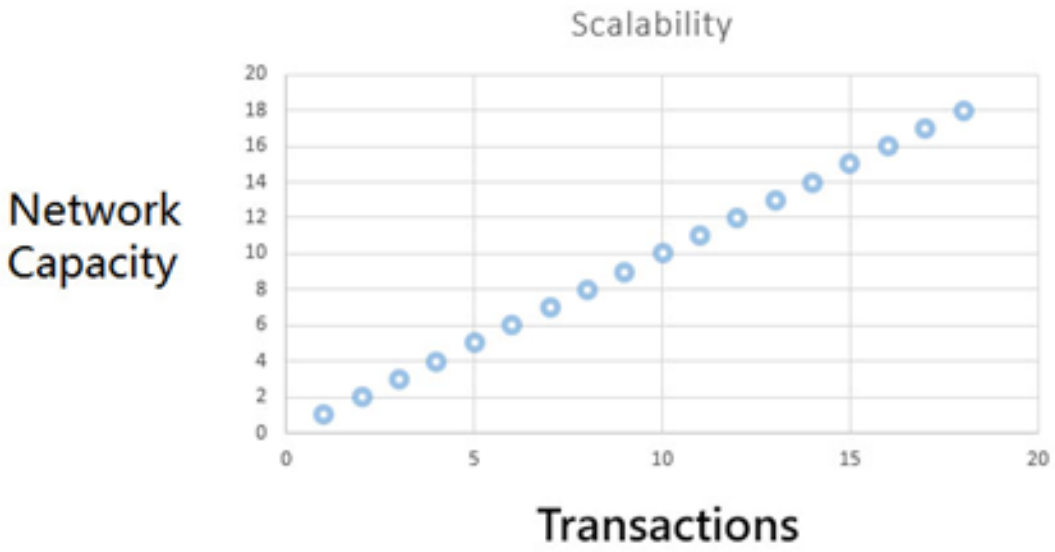
Comparison of Tangle & Blockchain

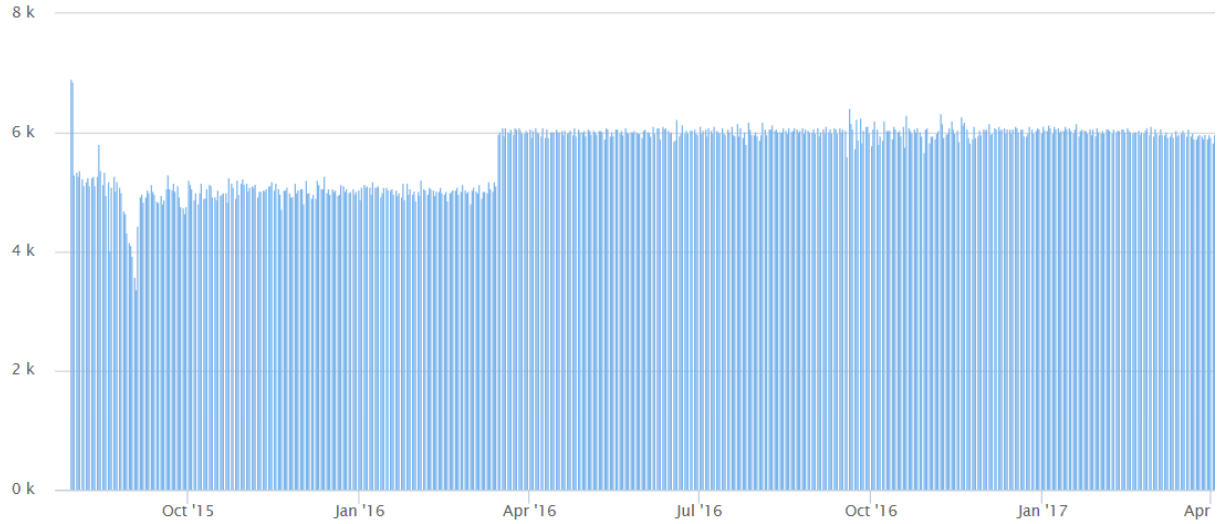


Comparison

Scalability



Blocks per day



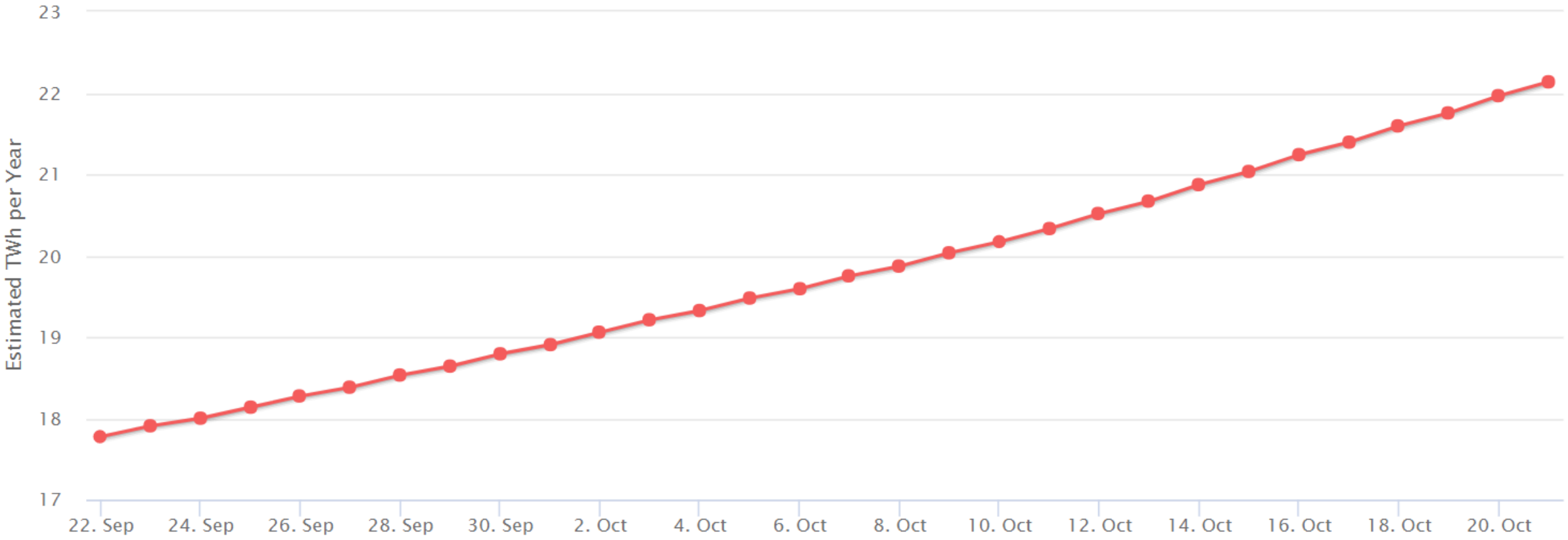
Comparison

Fees & Time to Confirmation

	Buyer	Merchant
Tangle	PoW ↑ ⟹ Propagation ↑	Specific percentage of consensus.
Blockchain	Fee ↑ ⟹ Mined ↑	Specific number of blocks building on top of this block.

Comparison

Energy Consumption



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The backbone of IoT is here!

IOTA

Specific Concepts

1. The Coordinator
2. Peer discovery
3. Snapshots

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Conclusion & Outlook

Concepts behind IOTA’s Tangle

How to issue transactions

Feeless, scalable, immutable ledger

Smart contracts

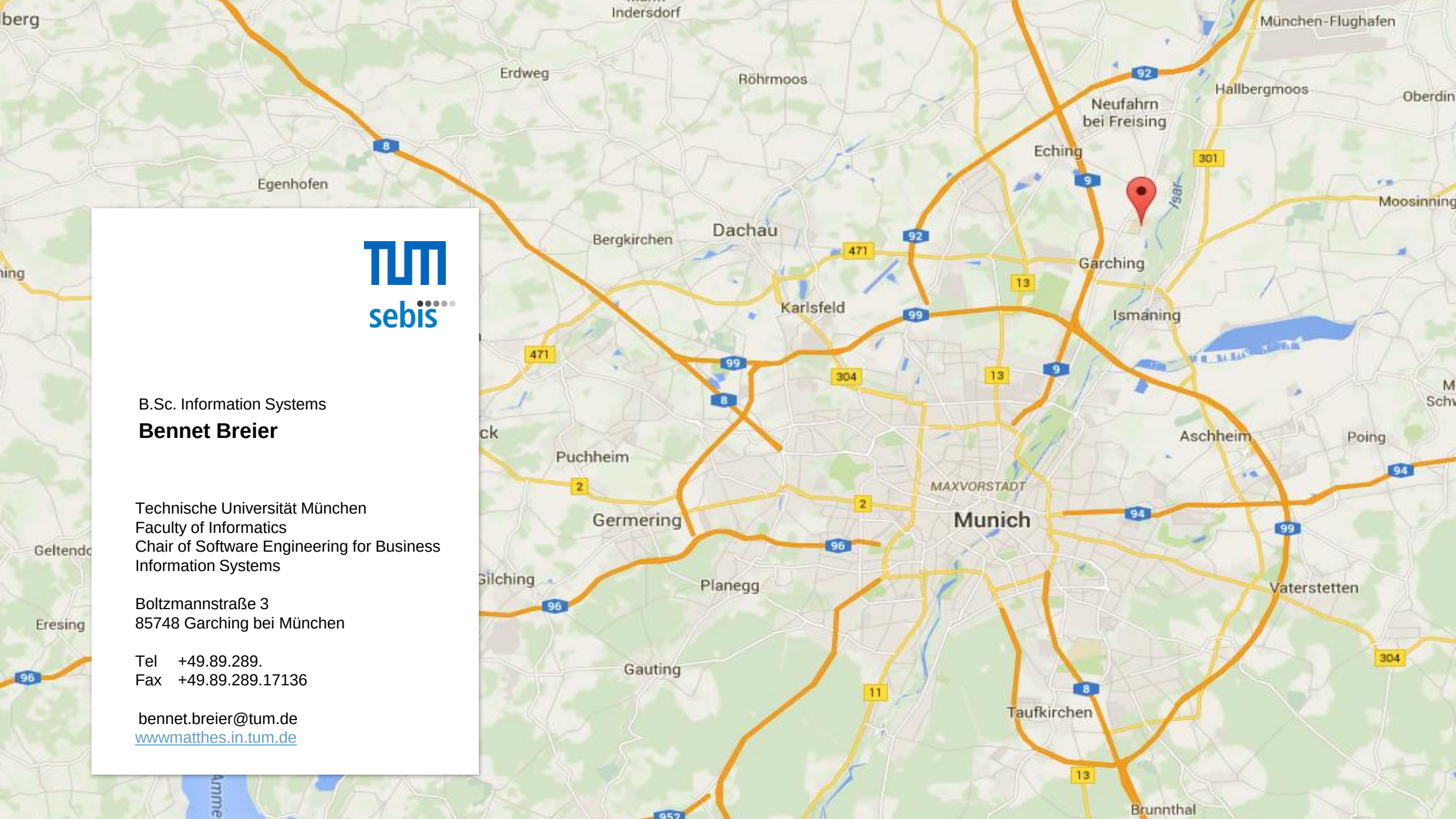
Energy consumption

Cryptographic security & the coordinator

Concrete use-cases

Thank you for your attention

Further questions?



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Backup

```
[
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            "ZHITHKLKRZEY9HJCWH9DBLIHZLWB9OUMSKZHNAEQVMPSMQYWYJHUJRZHIJI
             GJBUSHLXLWETVWNFWLPZAL",
        "balance": "50000000"
    },
    {
        "address":
            "DWVNBUBSTUTSEB9KZPATIKHDJPZGEEFATMIGZFKQZTAYVZ99GNQAMQVNRBS
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        "balance": "200000000000"
    },
    ...
]
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