Blockchain Consensus Protocol with Horizontal Scalability

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Outline

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The dangers of centralisation

- Technological advancements give us convenience
- But it puts central authorities in control
- Many are motivated by profit
- Not always in the interest of the "users"[1]

[1] Typically users of some free service X are, in fact, used by X.

The dangers of centralisation: Examples

- Facebook can predict your opinions and desires better than your spouse [1]
- With intimate knowledge of the individuals, Facebook creates "psychographic" profiles in political campaigns [2]
- Baidu's promoted search result on experimental medical care caused death of a student [3]

Blockchain: a new hope?

- Blockchains are distributed ledgers
- They enable large scale consensus
- An alternative to central authorities for the first time
- Some applications include:
  - Digital cash (e.g., Bitcoin)
  - Domain name system (e.g., Namecoin)
  - File sharing (e.g., Filecoin)
  - General purpose (e.g., Ethereum)

Blockchain: not there yet

- Consensus algorithm of early blockchain systems do not scale
- Bitcoin (PoW) is limited to 7 transactions per second
- 100,000 transaction backlog in May 2017
- We require horizontal scalability for ubiquitous use
- More nodes = better performance and throughput

Related work

Table: Summary of the scalability properties of many blockchain systems. Scalability gets better from left to right.

Not scalable	**Somewhat scalable**	**Limited horizontal scalability**	**True horizontal scalability**
Bitcoin Ethereum etc.	Hyperledger ByzCoin Solidius	Elastico OmniLedger Lightning Network	CHECO (this work)

Related work

State-of-the-art: Sharding

- Split state into multiple shards
- Shards run consensus algorithm in parallel
- Difficult to perform atomic inter-shard transactions
    - Elastico: not possible
    - OmniLedger: via Atomic Commit protocol
- Additional complexity
- Diminishing return

Research question

How can we design a *blockchain consensus protocol* that is *fault-tolerant*, *horizontally scalable*, and able to reach *global consensus?*

Outline

Intuition

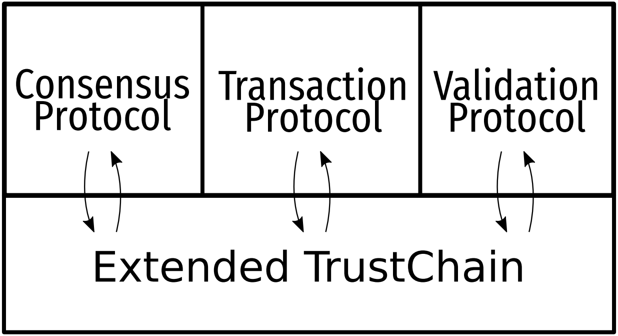
- Traditionally: to reach consensus and check the validity of all transactions is expensive
- Our idea: we decouple consensus and validation
- Use a single digest to represent an arbitrarily large number of transactions
- Reach consensus on the small digest
- Nodes then independently check the validity of the transactions of interest

System model

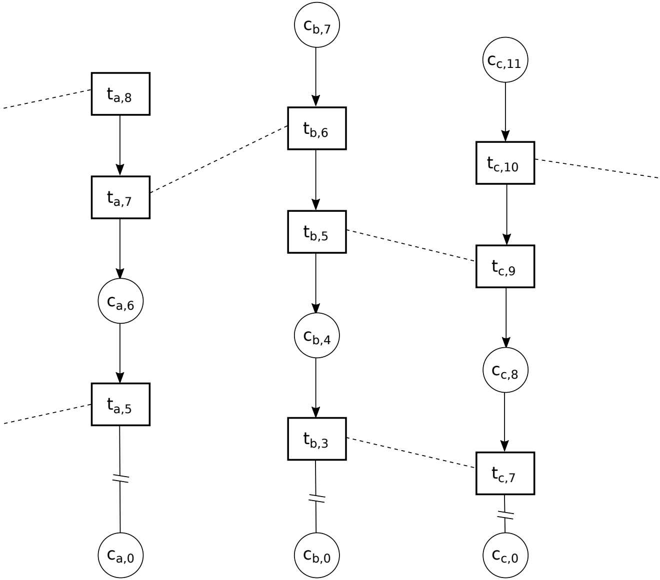
- N is the population size
- Purely asynchronous channels with eventual delivery
- n nodes are facilitators
- t nodes are malicious, i.e. Byzantine
- $n \geq 3t + 1$
- $N \geq n + t$

Architecture overview

The four components of CHECO



Extended TrustChain



Extended TrustChain: TX block

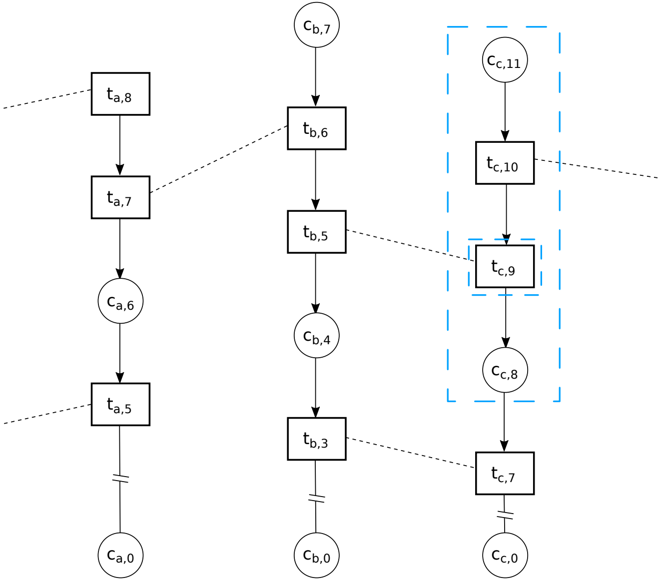
1. Hash pointer to the previous block
2. Sequence number
3. Transaction ID
4. Public key of the counterparty
5. Transaction message m
6. Signature the five items above

A transaction is represented by a *pair* of TX blocks

Extended TrustChain: CP block

1. Hash pointer to the previous block
2. Sequence number
3. Digest of consensus result, i.e. a set of CP blocks
4. Round number r
5. Signature on the four items above

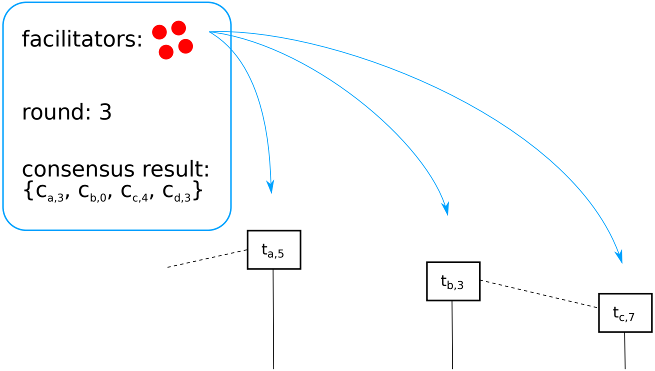
Extended TrustChain: Fragment of a TX block



Consensus protocol—Background on ACS

- Asynchronous common subset
- A simplification of HoneyBadgerBFT [4]
- n nodes
- t nodes may be malicious
- Input: every node proposes a set of values, e.g., $\{A, B\}, \{B, C\}, \ldots$
- Output: set union of the majority, e.g., $\{A, B, C, \ldots\}$

Consensus protocol

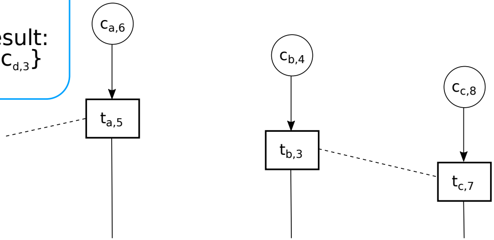


Consensus protocol

facilitators:

round: 3

consensus result: $\{c_{a,3}, c_{b,0}, c_{c,4}, c_{d,3}\}$

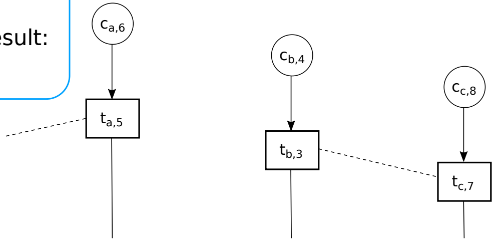


Consensus protocol

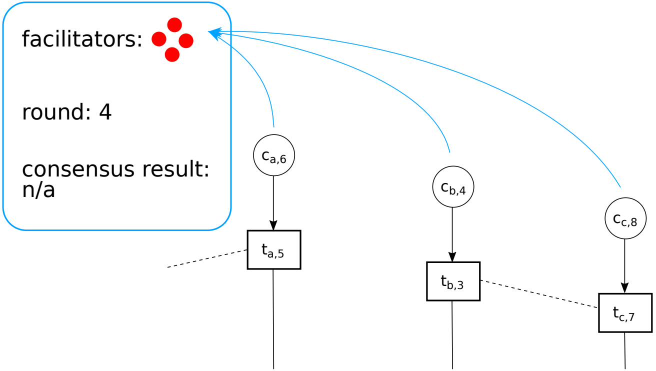
facilitators: lottery
$\{c_{a,3}, c_{b,0}, c_{c,4}, c_{d,3}\}$

round: 4

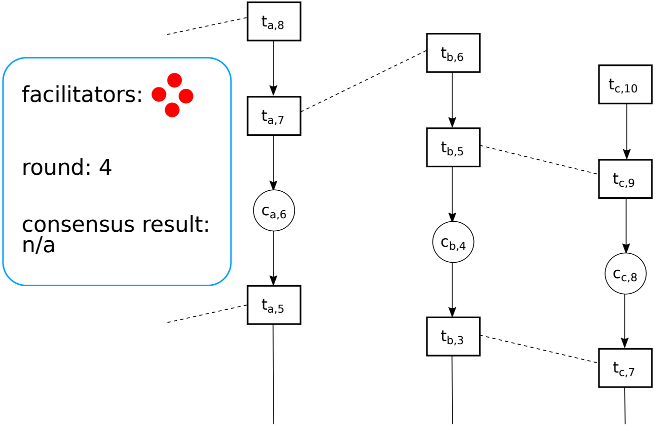
consensus result:
n/a



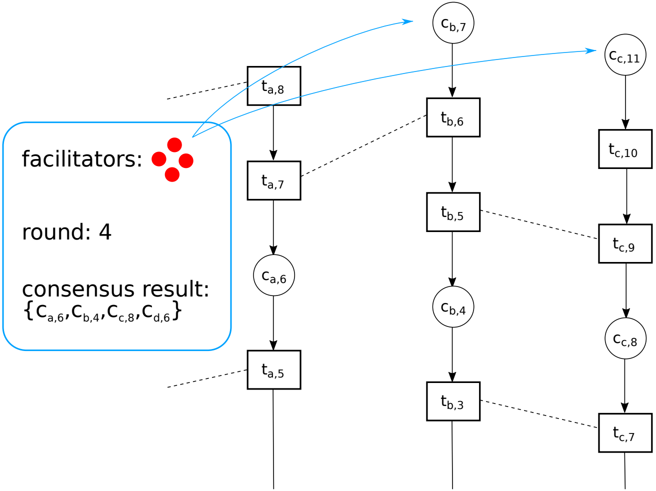
Consensus protocol



Consensus protocol



Consensus protocol

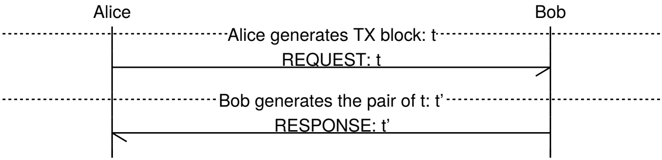


Consensus protocol: properties

The consensus protocol has the following properties in every round r.

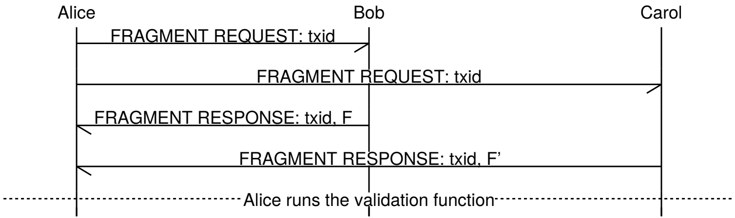
- *Agreement*: Every correct outputs the same set of facilitators.
- *Validity*: The consensus results is valid such that a new set of facilitators can be computed from it.
- *Fairness*: Every node with a CP block in the consensus result should have an equal probability of becoming a facilitator.
- *Termination*: Every correct node eventually outputs a set of facilitators.

Transaction protocol



- Request and response protocol
- Two TX blocks containing the same *txid* are generated
- Non-blocking

Validation protocol



- Alice needs the two fragments that belong to the transaction
- Validation function checks whether the fragments are OK and contain the transaction
- Non-blocking

Validation protocol: properties

- CP blocks of the fragments are "anchored" due to the consensus protocol
- It is difficult to modify the fragment once "anchored"
- Implicit consensus on transactions via CP blocks

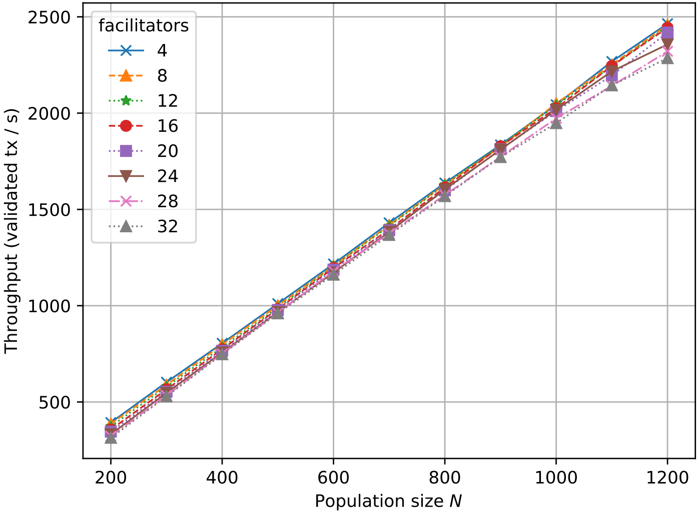
Outline

Implementation and experiment setup

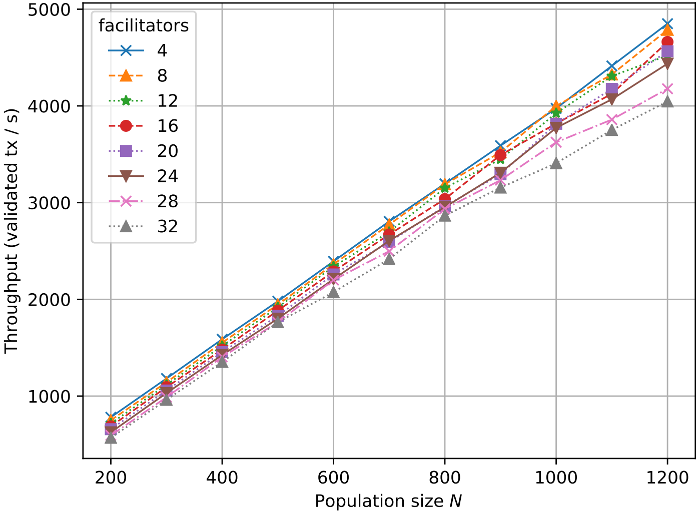
- Free and open source implementation on Github:
  `https://github.com/kc1212/checo`
- SHA256 for hash functions and Ed25519 for digital signature
- Experiment on the DAS-5[2]

[2] `http://www.cs.vu.nl/das5/`

Throughput vs population size (random neighbour)



Throughput vs population size (fixed neighbour)



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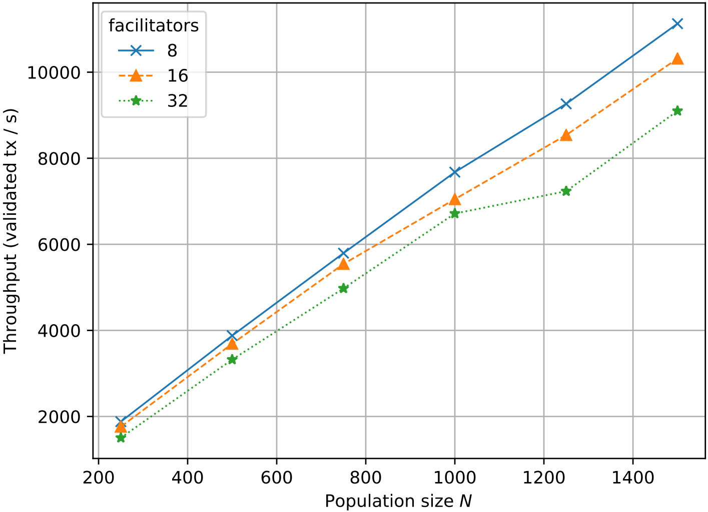

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Conclusion

Out work answers the research question.

How can we design a *blockchain consensus protocol* that is *fault tolerant*, *horizontally-scalable*, and able to reach *global consensus?*

Future work

- Implement and experiment with a concrete application
- Analyse the system in the permissionless environment
- Improve fault tolerance

Bibliography

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