Synchronization Requirements of Token Smart Contracts

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NEC Labs Europe

Based on joint work with:

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University of Bern

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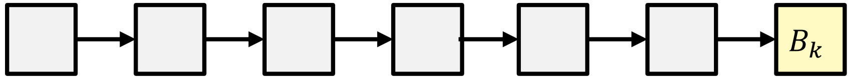
Bologna, Italy

Motivation



- Decentralized applications rely on a distributed protocol emulating a shared ledger (blockchain)

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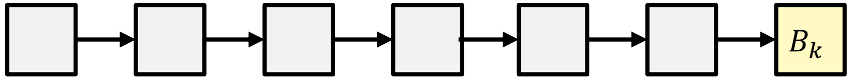

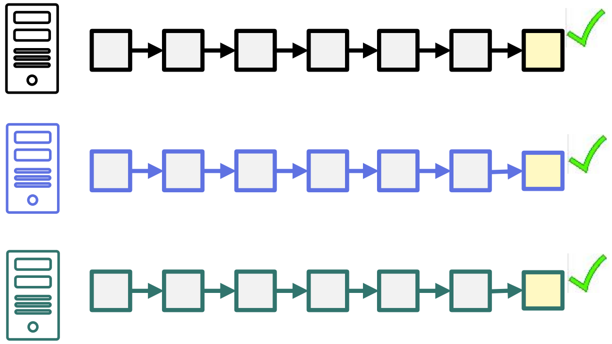

- Decentralized applications rely on a distributed protocol emulating a shared ledger (blockchain)
- Distributed consensus (a.k.a. total-order broadcast) ensures consistency among ledgers

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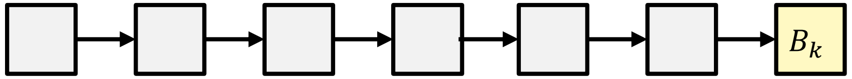

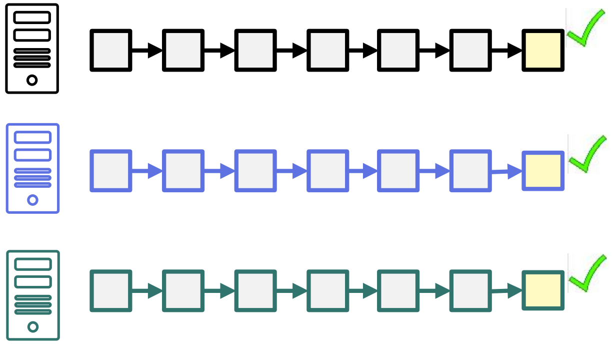

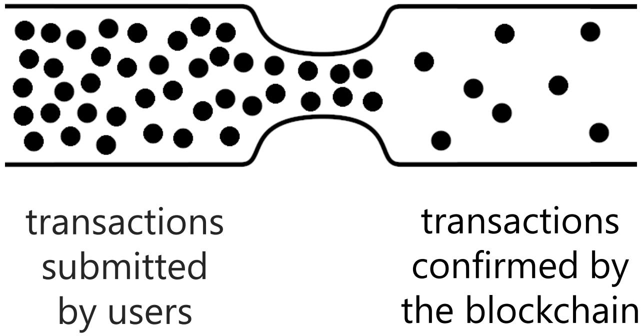
transactions submitted by users
transactions confirmed by the blockchain

- Decentralized applications rely on a distributed protocol emulating a shared ledger (blockchain)
- Distributed consensus (a.k.a. total-order broadcast) ensures consistency among ledgers
- However, consensus is the bottleneck of blockchain speed ☹

Consensus is not necessary for decentralized cryptocurrencies (!)

Prior work [GKMPS’19]

[GKMPS’19] R. Guerraoui, P. Kuznetsov, M. Monti, M. Pavlovic, D.A. Seredinschi: **The consensus number of a cryptocurrency.** PODC 2019

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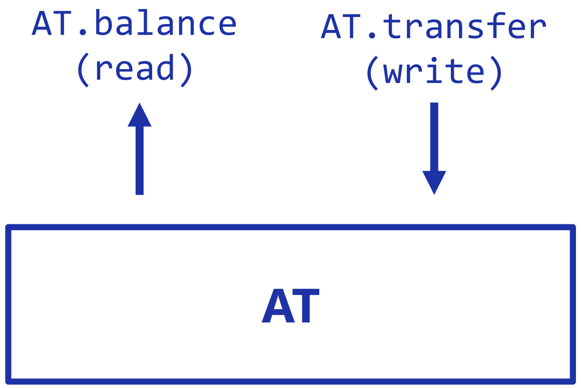
Approach:

- Define AT abstraction as shared-memory object
- Analyze the synchronization power (**consensus number**) of AT

Main result:
The consensus number of **AT** is 1 (range: $[1, \infty]$).

“Basic cryptocurrency functionality”
=
Asset Transfer (AT) object



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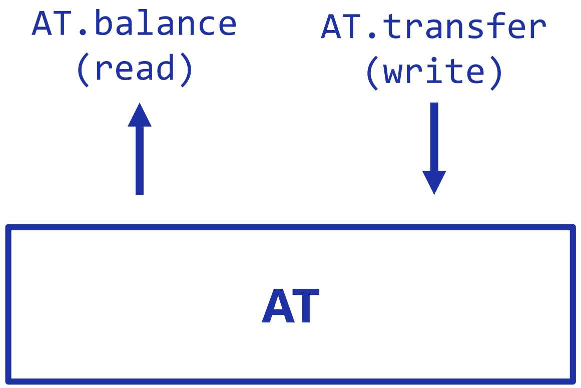

`AT.balance` (read)

`AT.transfer` (write)

AT

Interpretation:

- AT has weakest synchronization power
- Consensus is an overkill for basic cryptocurrency applications
- Intuitive reason: total order is not necessary to prevent double spending (causal order is enough)

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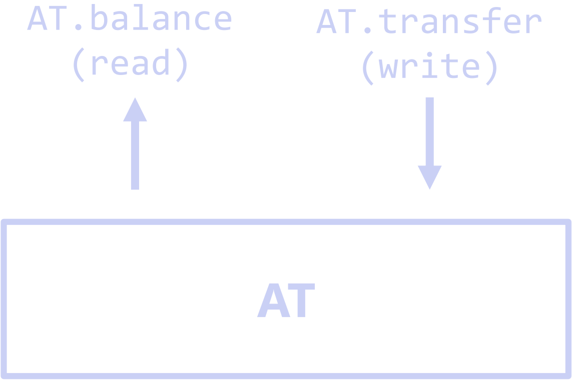
What about Smart Contracts?



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Synchronization power of Token Smart Contracts

This work [AC**M**Z'21]

Motivating question:
What level of synchronization is required for "popular" smart contracts?

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What level of synchronization is required for "popular" smart contracts?

ERC-20 token standard
(most popular fungible token in Ethereum)

Approach:

- Define ERC-20 abstraction as shared object **T**
- Analyze the consensus number of ERC-20 object

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New features compared to AT:

- Account owners can delegate approved spenders to manage asset
- Approval of spenders is dynamic (any time, arbitrary amounts)

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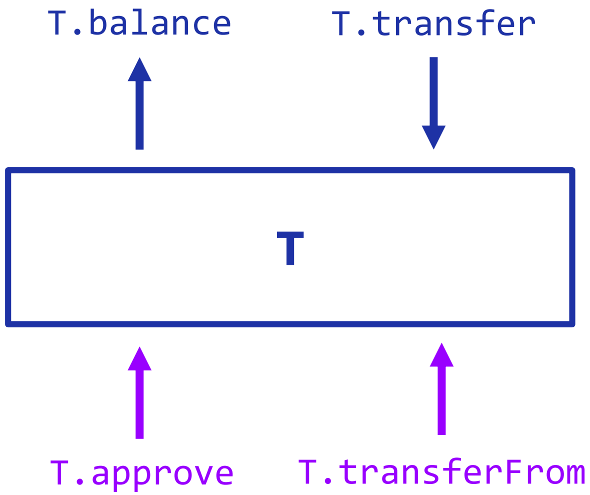

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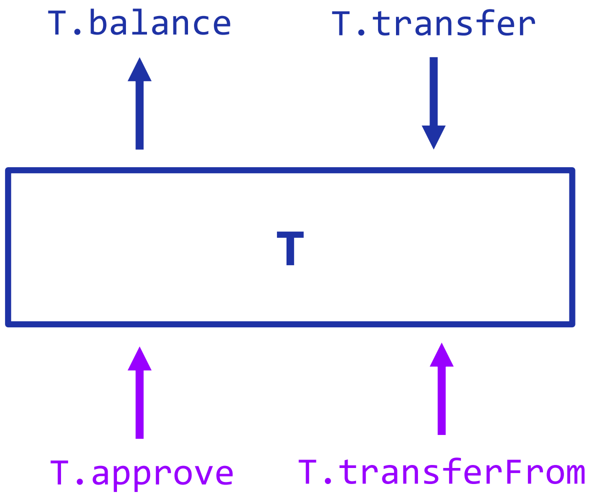

Main results:
The consensus number of **ERC-20 token T** dynamically changes with the contract state (q):

$$CN(T_q) = 1 + \max_{a} \{\#\text{ approved spenders for account } a\}$$

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Outlook

Prior work

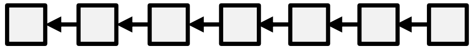
Synchronization power of **cryptocurrency**:

$$\boxed{CN(AT) = 1}$$

⇒ transactions can be processed concurrently
⇒ total order is not necessary, causal broadcast can be used instead

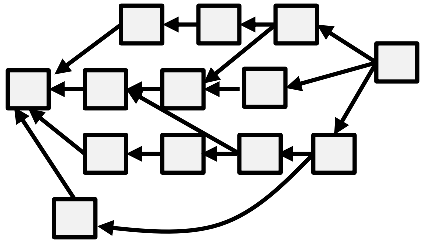
Currently adopted, an overkill

Total-order broadcast (blockchain)



Sufficient (faster, asynchronous!)

Causal broadcast



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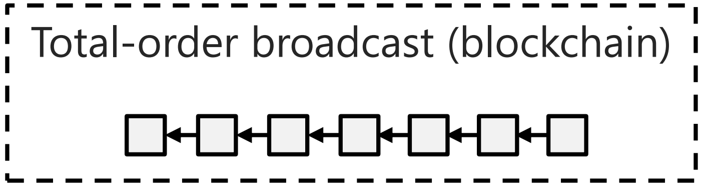

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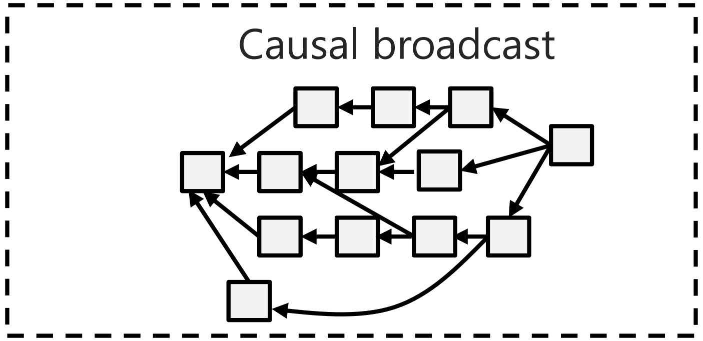


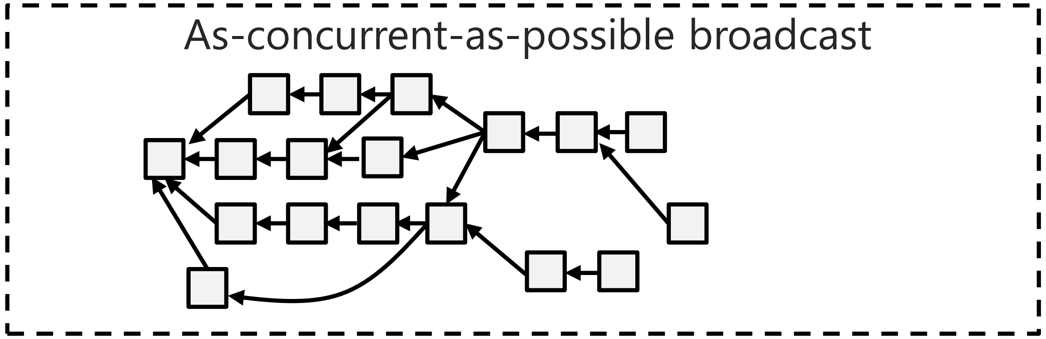
This work

Synchronization power of Ethereum **ERC-20 token T**:

$$\boxed{CN(T_q) = 1 + \max_a \{\#\text{ approved spenders for account } a\}}$$

⇒ transactions can be processed concurrently, if issued by spenders of different accounts
⇒ total order is needed only for resolving conflicts, causal broadcast could be used optimistically

Ideally: optimally-concurrent protocol for “useful” smart contracts



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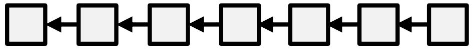

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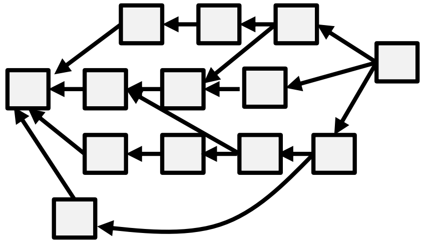

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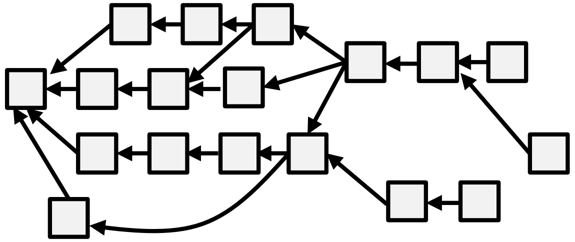
As-concurrent-as-possible broadcast



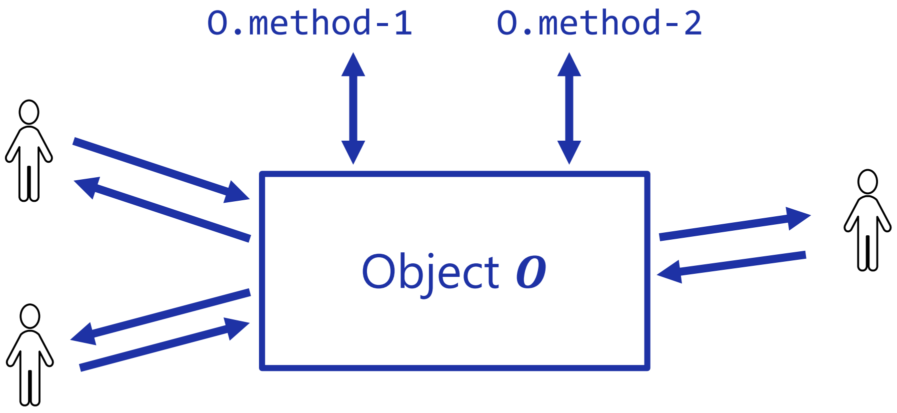
Thank you for your attention ☺

Backup slide

Synchronization power (consensus number) of shared objects

Wait-free hierarchy [Herlihy'91]

- Consensus is universal: any shared object has a wait-free implementation from consensus objects
- ⇒ consensus can serve as reference for the synchronization power of shared objects



Consensus number of object $\boldsymbol{O}$: $CN(\boldsymbol{O}) :=$
$max\ n$ | ∃ wait-free implementation of consensus object from objects of type $\boldsymbol{O}$ and registers, in a system with n processes.

- Intuitively: max # processes that can be synchronized "using $\boldsymbol{O}$"
  $CN(\boldsymbol{O}) = 1 \Rightarrow \boldsymbol{O}$ useless for synchronization
  $CN(\boldsymbol{O}) = \infty \Rightarrow \boldsymbol{O}$ can synchronize any number of processes
- Metric to compare synchronization power of shared objects

[Herlihy'91] M. Herlihy: **Wait-Free Synchronization.** ACM Trans. Program. Lang. Syst. 1991