Lockless Blockchain Sharding with Multiversion Control

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SIROCCO 2023
June 8th, 2023

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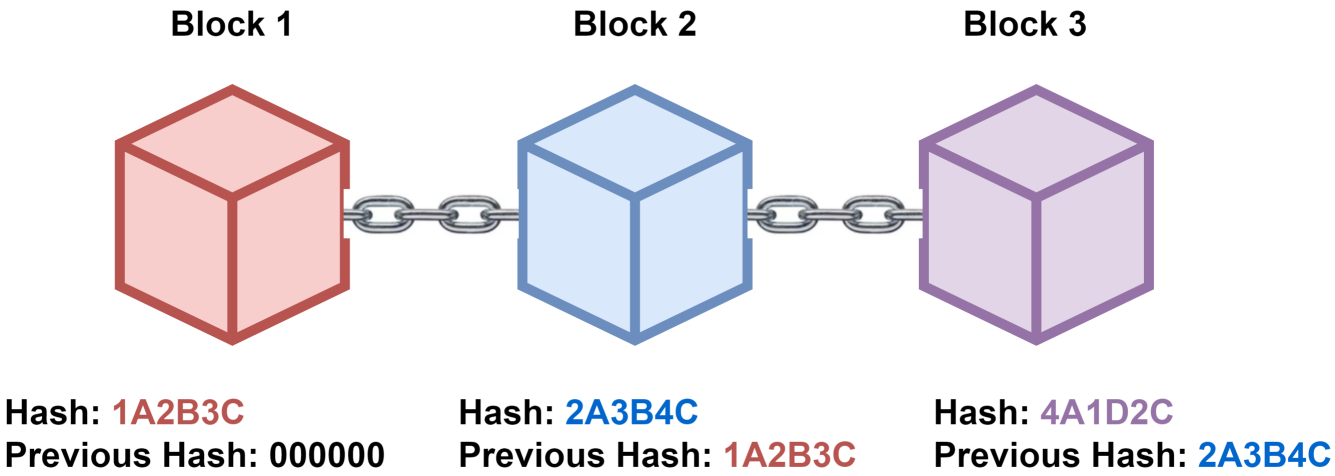
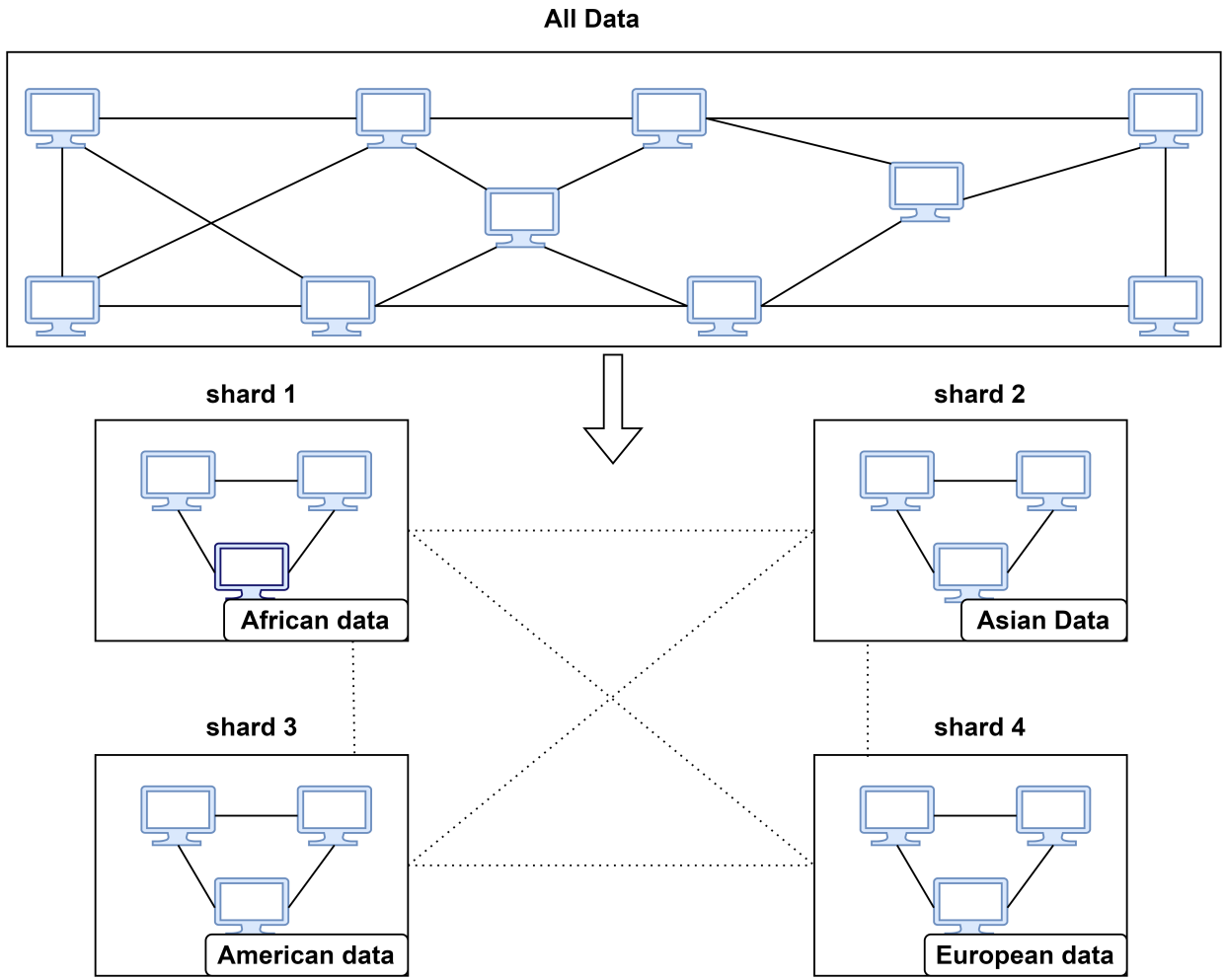
Blockchain and its Scalability Issues



- Blockchain is a chain of blocks that contains a transactions
- It requires all participants to agree on the validity of a transaction
- Increasing the number of nodes slows down transaction propagation and consensus

Solution: Blockchain Sharding

- Sharding splits transaction processing among smaller node groups
- These groups work in parallel to maximize performance



Transactions and Subtransactions for sharding

Example

T_1 = "Transfer 500 from Asma account to Rock account, if Asma has 500 and Rock has 1000".

- Suppose **shard a** holds Asma account and **shard r** holds Rock account
- So we split this transaction into two subtransactions as:
- $T_{1,a}$: "Check Asma has 500"
  : "Remove 500 from Asma acct"
  $T_{1,r}$: "Check Rock has 1000"
  : "Add 500 to Rock acct"

Example: Conflicting Transactions

Example

T_1 = "Transfer 500 from Asma account to Rock account, if Asma has 500 and Rock has 1000"

T_2 = "Transfer 200 from Rock account to Asma account, if Asma has 100 and Rock has 200"

$T_{1,a}$: "Check Asma has 500"
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$T_{1,r}$: "Check Rock has 1000"
: "Add 500 to Rock acct"

$T_{2,a}$: "Check Asma has 100"
: "Add 200 to Asma acct"

$T_{2,r}$: "Check Rock has 200"
: "Remove 200 from Rock acct"

Example: Sharding with conflicting Transactions

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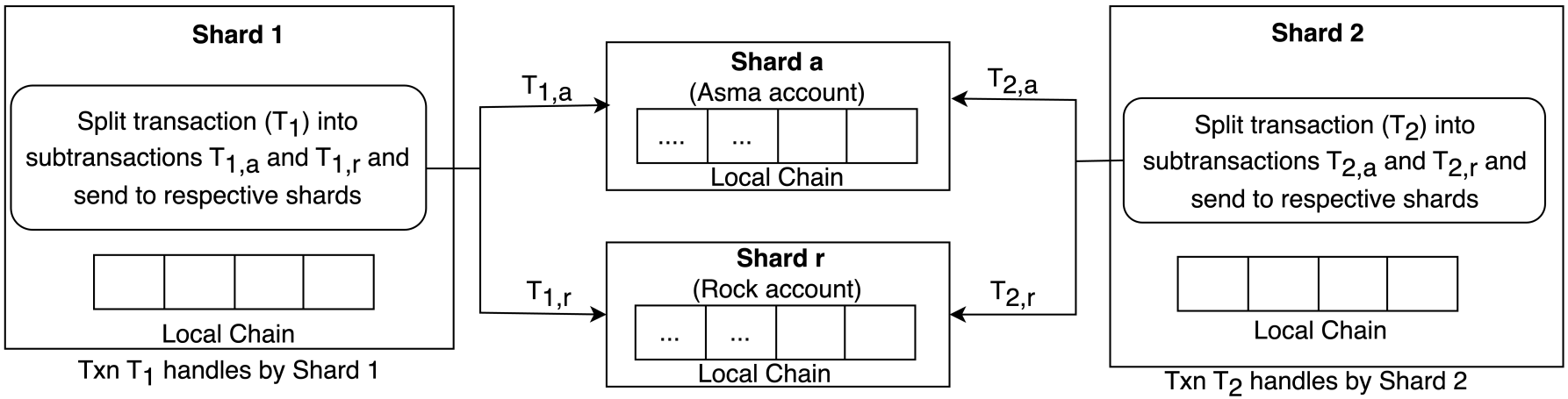
$T_{1,r}$: "Check Rock has 1000"
: "Add 500 to Rock acct"

$T_{2,a}$: "Check Asma has 100"
: "Add 200 to Asma acct"

$T_{2,r}$: "Check Rock has 200"
: "Remove 200 from Rock acct"



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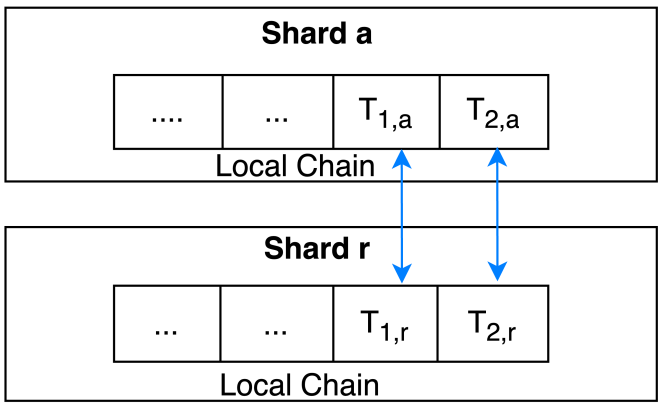

correct order of local commit in **Shard a** and **Shard r** can serialize transactions later

Serialization issue in sharding

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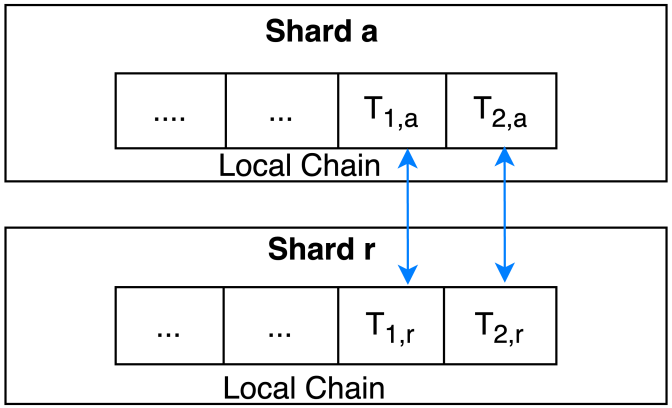

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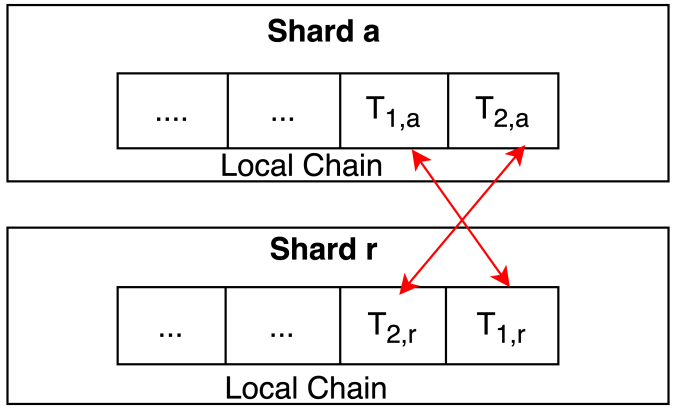

Incorrect order of local commit in **Shard a** and **Shard r** cannot serialize transactions later

Motivation and Related Work

- To use sharding, we need some kind of synchronization mechanisms to commit transactions and subtransactions safely in different shards
- However, existing sharding solutions like Byshard [1], OmniLedger [2] use locks for transaction isolation and concurrency control

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- Lock lowers the system throughput
- Hagar Meir et al. [3] present a lock-free method for transaction isolation, but they do not address a sharding-based blockchain model

Our Contributions

- We provide a lockless protocol for sharded blockchains
  - Instead of using locks, we use a multi-version approach for concurrency control
  - If conflicts occur between two transactions in any shard, one of them will restart

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  - Instead of using locks, we use a multi-version approach for concurrency control
  - If conflicts occur between two transactions in any shard, one of them will restart
- We provide formal correctness proofs for the safety and liveness of our proposed protocol
- We also provide an experimental analysis of our protocol

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Our Sharding Model

- Shard that initiates and handles the processing of the transaction called **Leader Shard**
- Shards that verify received subtransactions and append valid ones to their local ledgers, called **Destination Shard**

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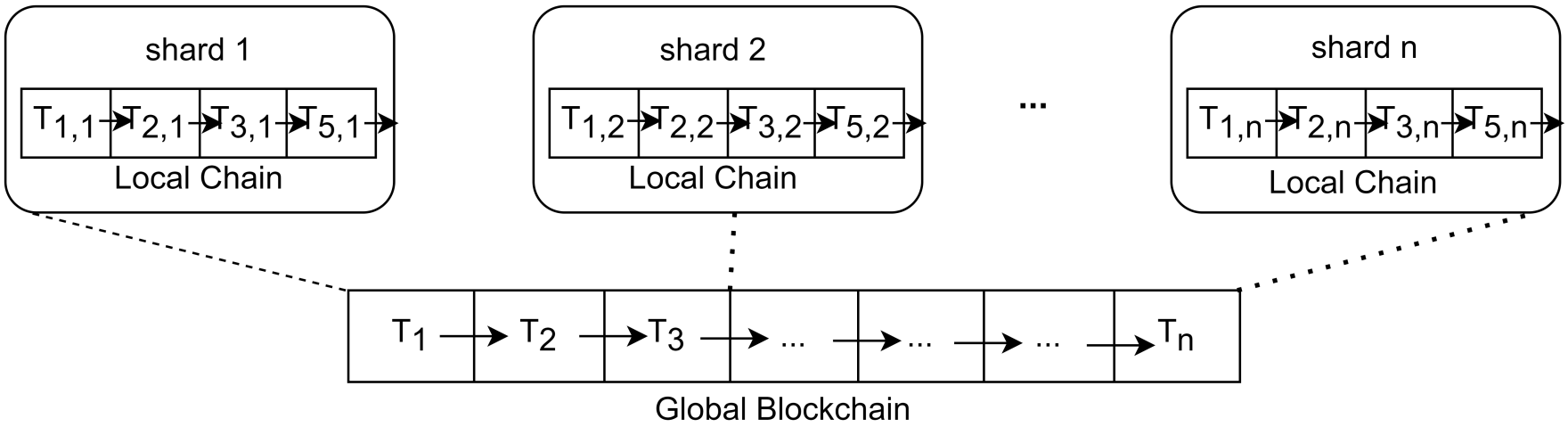
- Each shard only contains the local chain



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Sharding Algorithm

T_1 = Transfer 500 from Asma Account to Rock account, if Asma has 500 and Rock has 1000

$T_{1,a}$: "Check Asma has 500" & "Remove 500 from Asma account"

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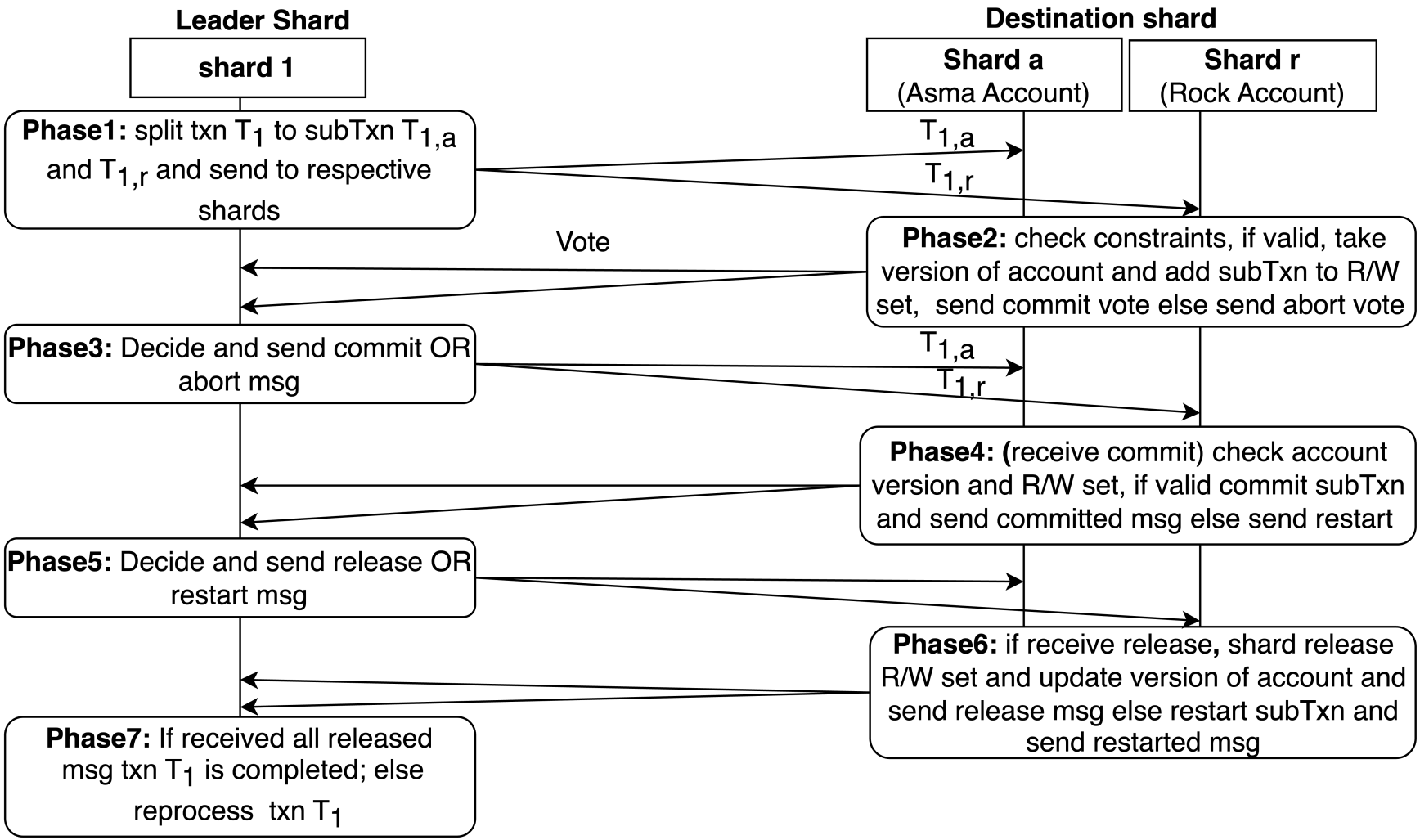

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- Let $T_{1,a}$ has finished executing phase 2. Hence, $\mathbf{T_{1,a}}$ **has been added to write set W(Asma)**

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- Let $T_{1,a}$ has finished executing phase 2. Hence, $\mathbf{T_{1,a}}$ **has been added to write set W(Asma)**
- Later, when $T_{2,a}$ reaches phase 4 (i.e Commit phase)
  - It will observe $\mathbf{T_{1,a}}$ **is already in W(Asma)** which will force $T_{2,a}$ to restart
  - On the other hand, if T_1 completed and updated the version of Asma. Then $T_{2,a}$ will restart by observing the updated version of Asma
- In either case, one of the two transactions will restart

Our protocol provides Liveness

Our protocol guarantees that every transaction will eventually commit

Our protocol provides liveness by **prioritizing transaction** execution

- Periodically, each shard sends its lowest transaction ID to other shards
- In case of conflict, priority is given to lowest ID

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- Periodically, each shard sends its lowest transaction ID to other shards
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- Suppose two subtransactions $T_{1,a}$ and $T_{2,a}$ conflict in **shard a**
- Assume T_1 has highest priority
- Suppose subtransaction $T_{2,a}$ is in between the phase 2 and 6
- Then when $T_{1,a}$ reaches phase 4. It will observe inprocessing of $T_{2,a}$. As $T_{1,a}$ has the highest priority to execute which will force $T_{2,a}$ to rollback while $T_{1,a}$ make progress

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Experimental Analysis

- Transaction execution time of protocol is better than the lock-based protocol

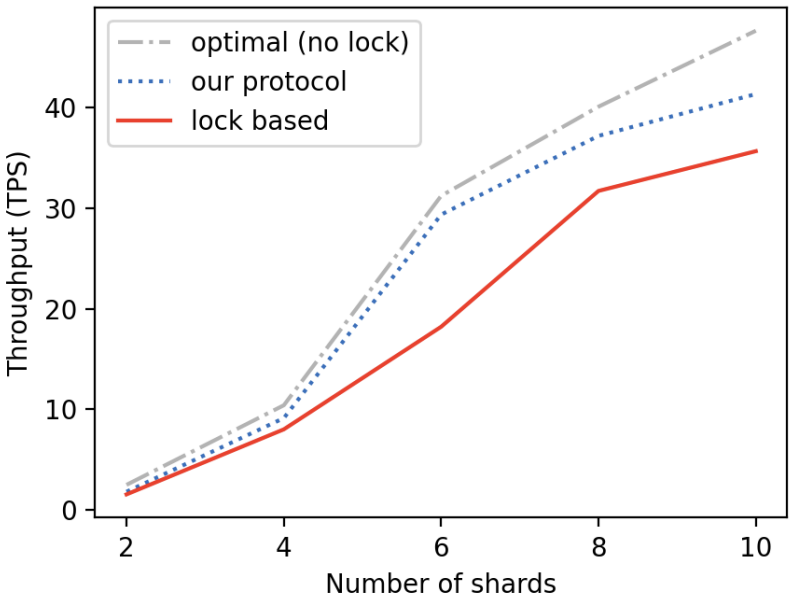

Figure: (1). Average transaction throughput with the number of shards

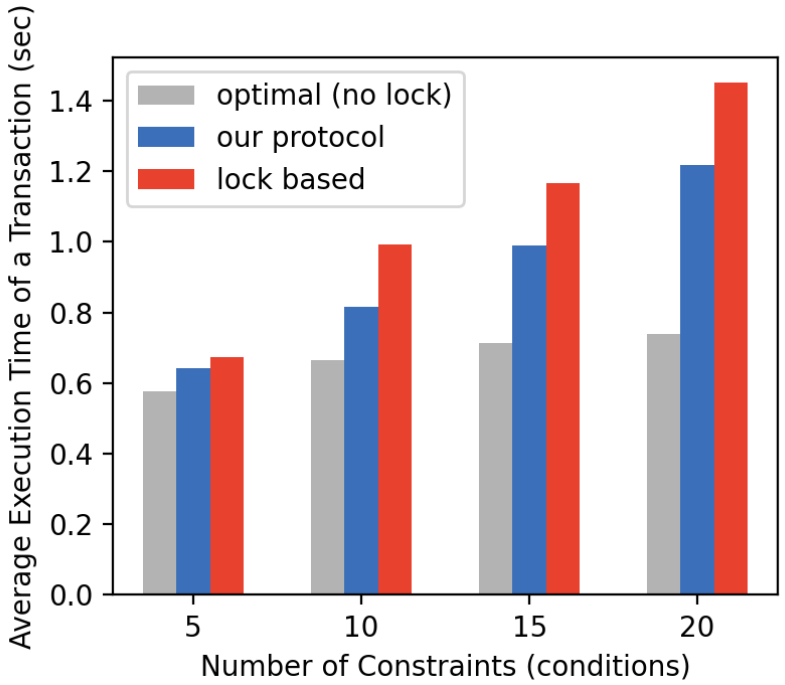

Figure: (2). Average execution time of a transaction with numbers of constraints

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Conclusion future work

- We presented a lockless transaction protocol for blockchain sharding
- Our protocol relies on taking versions of the shared objects
- Proposed protocol achieves faster transaction execution times compared to the lock-based approach

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- Our protocol relies on taking versions of the shared objects
- Proposed protocol achieves faster transaction execution times compared to the lock-based approach
- Future work: Explore efficient communication between shards

References

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Thank you!