[Draft] RISE pevm: Blazingly Fast Parallel Executor for EVM Blockchains

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Abstract

RISE pevm is a parallel EVM executor heavily inspired by Block-STM. We made several contributions to improve performance, especially when Aptos designed Block-STM for MoveVM instead of EVM. Most notable is the introduction of lazy updates to remove explicit reads and dependencies in common transaction scenarios. Our implementation is open-source at `https://github.com/risechain/pevm`. The reproducible benchmarks show that RISE pevm is the fastest EVM block executor, with a peak speedup of 22x and a peak raw execution throughput of 55 Gigagas/s on 32 AWS Graviton3 CPUs. RISE pevm also enables new possibilities for parallel EVM dApp designs.

1 Introduction

Parallelizing execution to accelerate blockchain throughput has gained popularity thanks to Aptos, Sui, and Solana. However, it is still unfruitful in the EVM land. Early adaptions of Block-STM[1] by Polygon and Sei have shown limited speedup due to the lack of EVM-specific optimizations and implementation limitations. Both Polygon and Sei use Go, a garbage-collected language unsuitable for optimizations at the micro-second scale. Parallel execution in Go is mostly slower than sequential execution in Rust and C++ for Ethereum mainnet blocks today.

RISE pevm sets to address this problem by designing an EVM-specialized parallel executor and implementing it in Rust to minimize runtime overheads. The result is the fastest EVM block executor, with a peak speedup of 22x and a raw execution throughput of 55 Gigagas/s on 32 AWS Graviton3 CPUs. RISE pevm also enables new parallel dApp designs for EVM like Sharded AMM[2].

While others embed their parallel executor directly into their nodes, we built a dedicated repository to serve as a playground for further pevm R&D. The code base is open-source at `https://github.com/risechain/pevm`.

2 Foundation

Blockchain execution must be deterministic for network participants to agree on blocks and state transitions. Therefore, parallel execution must arrive at the same outcome as sequential execution. Having race conditions that affect execution results would break consensus.

2.1 Block-STM

RISE pevm builds on Block-STM's optimistic execution based on Software Transaction Memory[3] and Optimistic Concurrency Control[4]. We also use a multi-version data structure to record the memory locations that each transaction reads and writes to. The collaborative scheduler has validation tasks to re-execute transactions that yielded state conflicts. The scheduler finishes when all transactions pass validation and arrives at the same result with sequential execution.

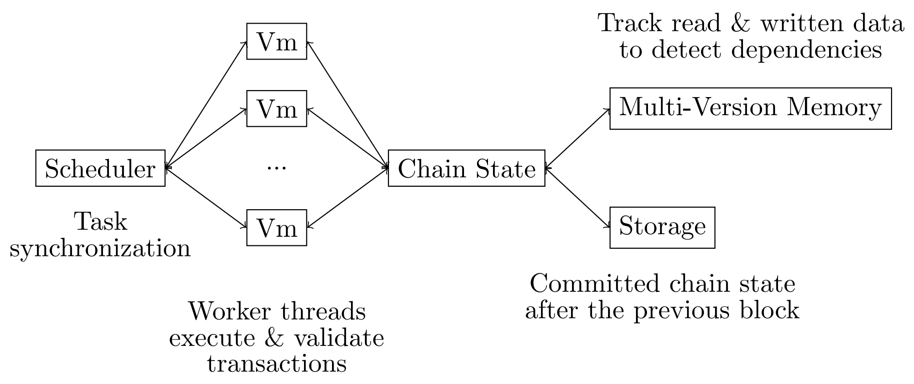
3 Contributions

We made several contributions both generally and fine-tuned for EVM.

3.1 Lazy Updates

All EVM transactions in the same block read and write to the beneficiary account for gas payment, making all transactions interdependent by default. RISE pevm addresses this by lazy-updating the beneficiary balance. We mock the balance on gas payment reads to avoid registering a state dependency and only evaluate it at the end of the block or when there is an explicit read. We apply the same technique for common scenarios like raw ETH and ERC-20 transfers. Lazy updates help us parallelize transfers from and to the same address, with only a minor post-processing latency for evaluating the lazy values.

4 Architecture



Track read & written data to detect dependencies
Vm
Vm
...
Vm
Scheduler
Chain State
Multi-Version Memory
Storage
Task synchronization
Worker threads execute & validate transactions
Committed chain state after the previous block

5 Implementation

6 Integration

7 Evaluation

8 Future Works

8.1 Preprocessed Dependencies

We can add a list of preprocessed dependencies to the scheduler to only execute a transaction after executing all of its dependencies. This list can be computed internally by pevm inspecting the input block or externally by an advanced mempool. While this technique helps minimize re-execution, it still resorts to sequential execution for dependent transactions. Lazy updates are much more potent as they execute dependent transactions in parallel for only a minor post-processing cost. For instance, we used to pre-define dependencies across transactions of the same sender and recipient, which we eventually replaced with lazy updates for 2-3x speedup. Nevertheless, this technique remains helpful for state dependencies that cannot yet be lazy-updated.

8.2 Extended Block Metadata

Block builders and executors can inspect each transaction's final read and write set for valuable metadata that improves downstream execution speed.

Transaction Dependency Graph: Syncing nodes can fork-join block execution according to a transaction dependency graph. Each parallel fork executes a chain of dependent transactions sequentially. All forks join at the end for post-processing. This optimal process yields no state conflict and re-execution. A single full-block validation at the end confirms the execution result.

Read Memory Locations: Syncing nodes can concurrently preload to-be-read memory locations to avoid blocking I/O during transaction execution.

Blacklisting: Malicious metadata like enormous read memory locations can significantly slow down or even crash syncing nodes. Therefore, syncing nodes must have strict bounds while parsing and blacklist nodes that provide bad metadata, either to not receive more blocks or to not process extended metadata from them. Sensitive nodes can go further by only whitelisting trusted nodes. Nevertheless, if the full-block validation fails after executing with a dependency graph, the syncing node can still fall back to optimistic execution.

9 Conclusion

References

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[4] H. T. Kung and John T. Robinson. 1981. On optimistic methods for concurrency control. ACM Trans. Database Syst. 6, 2 (June 1981), 213–226.