Persian: A fast checkpointing based on concurrent prefix recovery

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1. Introduction

Recovery and ACID Properties

In modern key-value stores, systems must recover quickly after a crash to avoid data loss and ensure reliability.

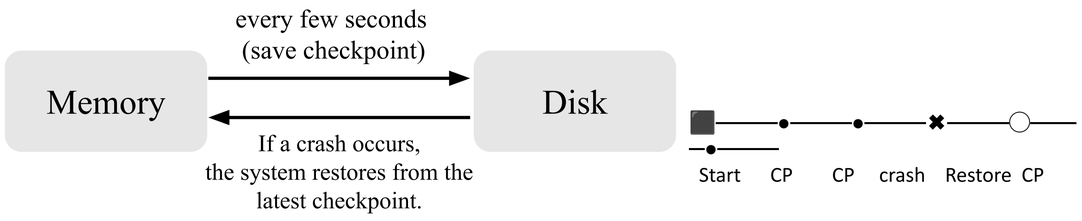
To achieve this, transactions follow the ACID properties. A transaction is a group of operations that must succeed or fail together.

Atomicity (all-or-nothing)	Consistency (data integrity)	Isolation (independent from others)	Durability (permanent once completed)

Checkpointing (CP)

Checkpointing is the main mechanism used to achieve Durability. It periodically saves in-memory data to persistent storage (disk).

When a crash occurs, the system restores from the latest checkpoint, reducing recovery time.



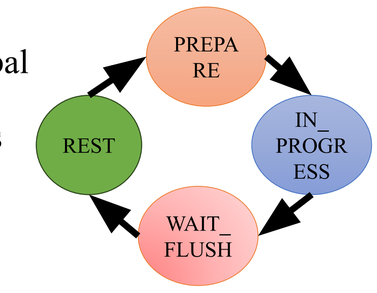
2. Conventional Method: CPR

Design

Concurrent Prefix Recovery (CPR) is a checkpointing technique designed to ensure Durability with minimal transaction interruption.

It runs concurrently with transactions and follows four phases :

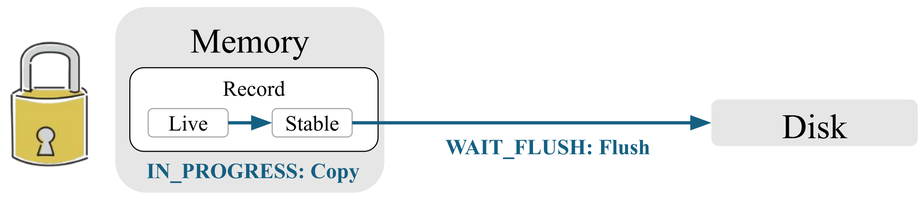
1. *PREPARE*: Initializes metadata and assigns a global checkpoint version.
2. *IN_PROGRESS*: Scans the in-memory log, copies valid records to a stable version.
3. *WAIT_FLUSH*: Flushes the stable version to disk asynchronously.
4. *REST*: Finalizes metadata and cleans up.



CPR enables asynchronous checkpointing, allowing transactions to proceed without pausing for the entire duration.

Challenge: Stable Copy Overhead

- Creating a stable copy incurs memory overhead.
- The process of scanning and copying records also introduces locking cost.



Research Question

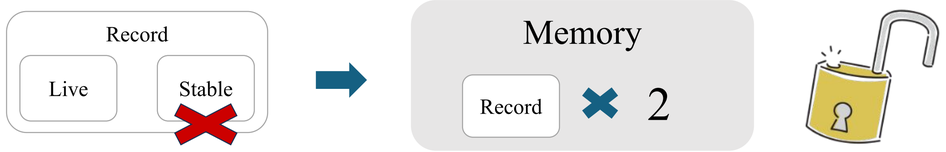
How to reduce checkpointing overhead?

3. Proposed Method: Persian

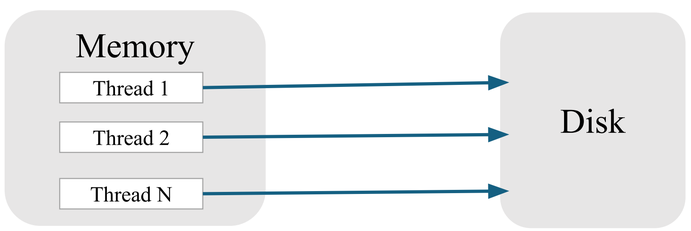
Persian removes the stable copy phase of CPR. It directly scans the in-memory log in the IN_PROGRESS phase, collects valid records, and flushes them to storage in parallel during WAIT_FLUSH.

This approach avoids locking and reduces memory usage.

Phase	CPR	Persian
IN_PROGRESS	Stable Copy	Eliminate Stable Copy ⇨ Save Memory ⇨ Remove Locks (Less Contention) ⇨Version Filter *(v-only scan)* ⇨ Prepare ensures consistency
WAIT_FLUSH	Single-thread Execution	Multi-thread Execution ⇨ Fast Flush & Scalable



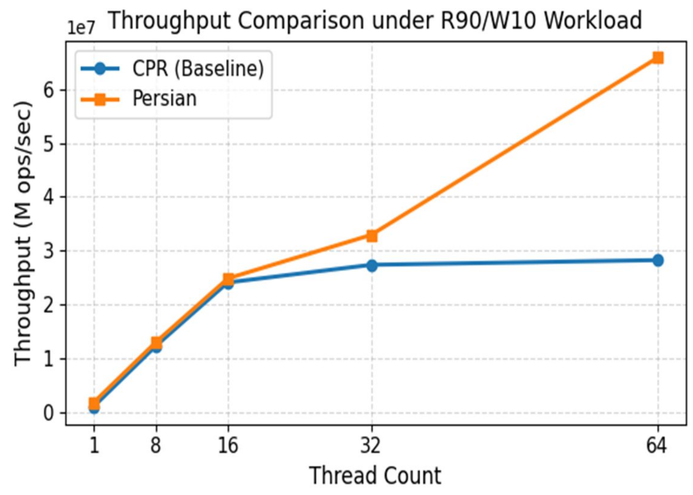
Persian reconstructs the version-v by scanning the log prefix and filtering records by version.



Hypothesis

Persian performs well under read-heavy workloads.

4. Results (YCSB-like Read Heavy)



Workloads:
90% Read /
10% Write

As the thread gets higher…

Throughput improves by up to 2× higher

Persian scales better under read-heavy loads, while CPR is slowed down by copying.

5. Conclusion

We proposed Persian to reduce CPR's overhead in read-heavy, high-concurrency workloads.

By eliminating stable copies and flushing in parallel, Persian avoids locking, achieving up to 2x higher throughput under read-dominant scenarios.

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