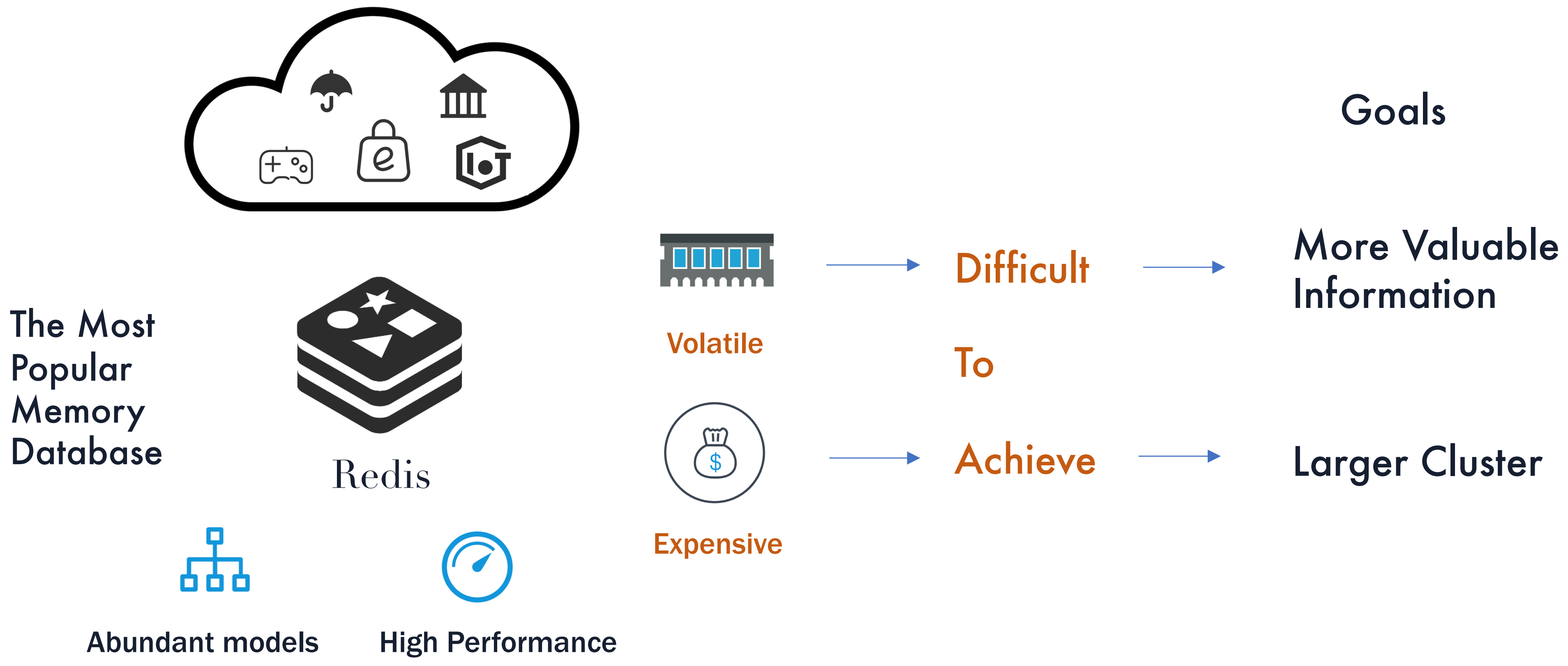
Tair-PMem: A Fully Durable Non-Volatile Memory Database

Caixin Gong, Chengjin Tian, Zhengheng Wang, Sheng Wang, Xiyu Wang, Qiulei Fu, Wu Qin, Long Qian, Rui Chen, Jiang Qi, Ruo Wang, Guoyun Zhu, Chenghu Yang, Wei Zhang, Feifei Li

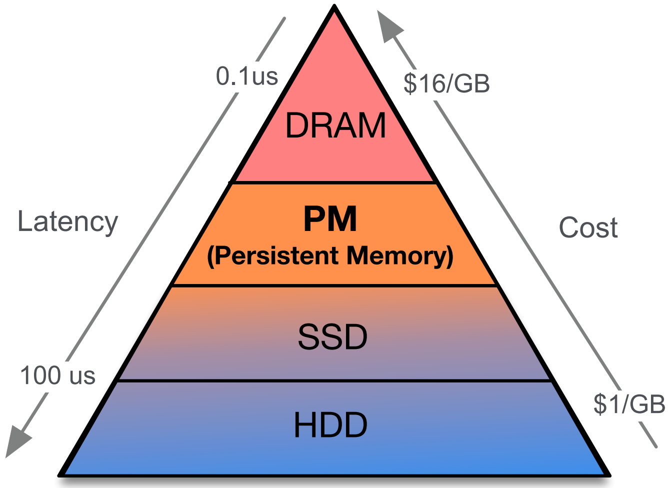
Alibaba Group

VLDB 2022

Redis Advantages & Disadvantages



Opportunities and Challenges



Intel Optane PM

Longer access Latency (3×)
Much lower Bandwidth (10×)

Challenge 1,
performance degradation

Enterprise Features

Abundant models

Challenge 2, Redis compatibility

Full durability

High Performance

Tair-PMem

more economical

Challenge 3,
NVM programming complexity

Outline

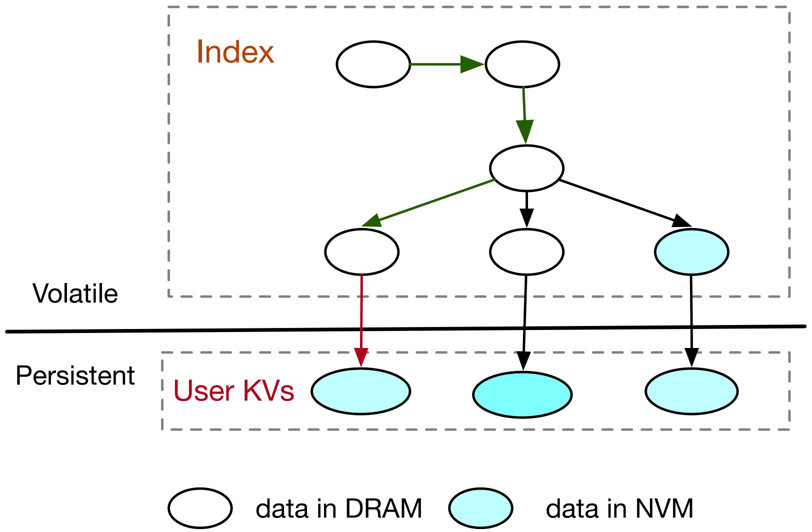
- Core Design Decisions
- The Database Architecture
- Evaluations

Decision 1: Hybrid Memory

- For performance
  - ➢ Keep index (small in size) in DRAM.
  - ➢ A small part of index may be stored in NVM.
  - ⭐ Most KV read takes only one NVM access.

Data Type	size	persistent	hot	location
User data	large	yes	-	NVM
MetaData of Allocator	small	no	yes	DRAM
Indexes	large	no	-	DRAM/NVM
Runtime variables	small	no	-	DRAM/NVM

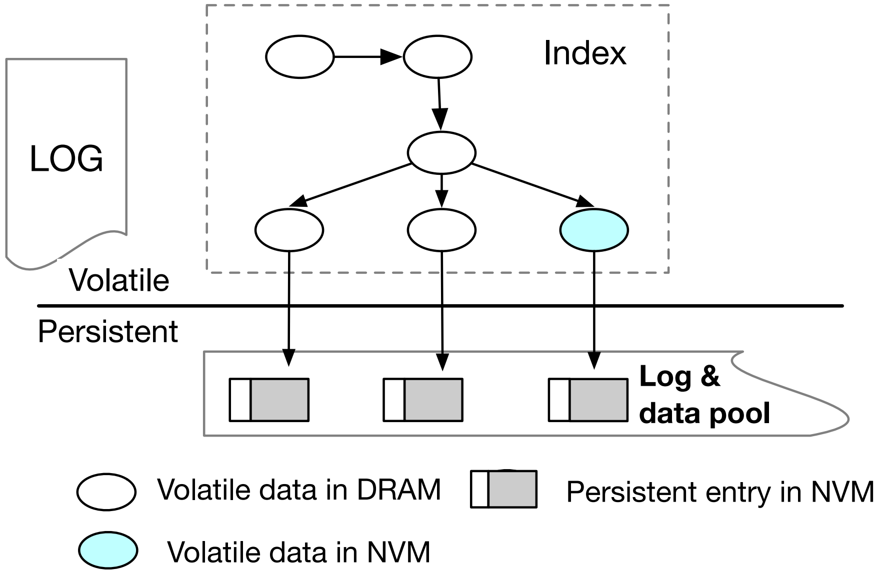
The characteristics of different data.



The hybrid memory structure.

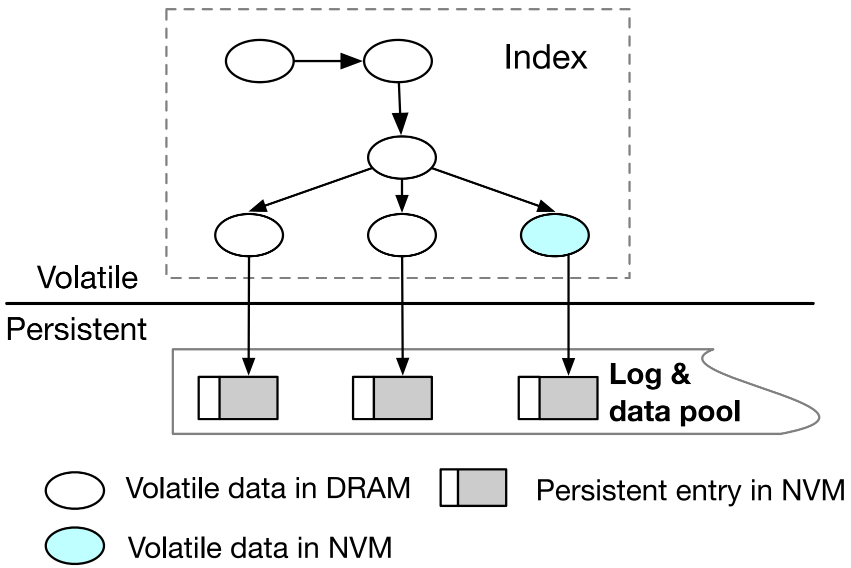
Decision 2: Log as Data

- What data should be persistent for durability, and How to organize them?
  - ⭐ **For Performance:** Log plays the role of user data, which makes user data only written once.
- How to recover
  - ➢ Redo the log to reconstruct indexes.



Decision 3: No Changes to Read Operation

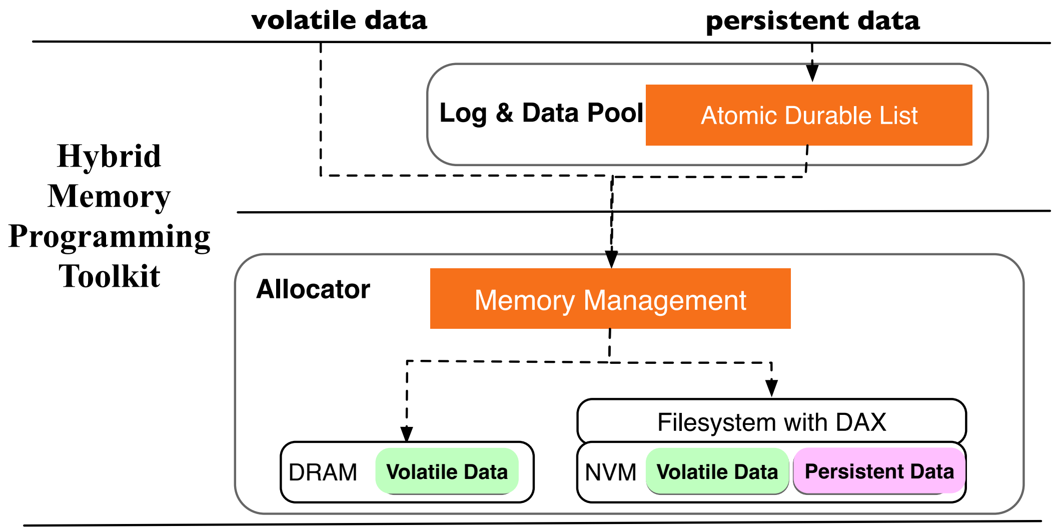
- **For easy programming**
  - ➢ User KVs encoded in *Log & data pool* keep the original format.
  - ⭐ Index need not be re-implemented, so as read operations.



Decision 4: Programming Toolkit

- A toolkit to hide the complexity of NVM programming
  - An allocator to manage both DRAM and NVM;
  - A component （the *Log & Data Pool*）to store all the persistent data;
  - high performance.

⭐ Easy Programming



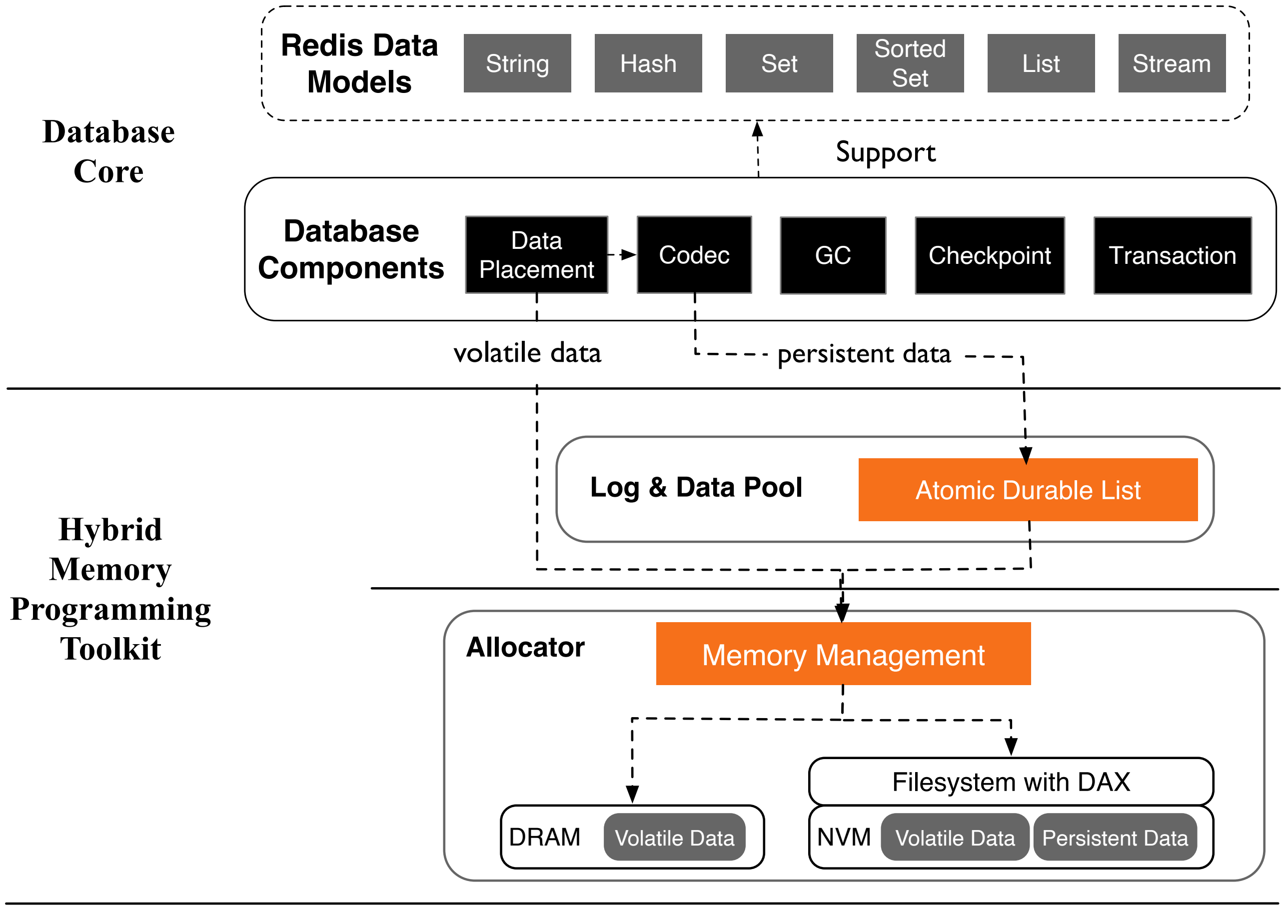
The structure of toolkit

Outline

- Core Design Decisions
- The Database Architecture
- Evaluations

Architecture

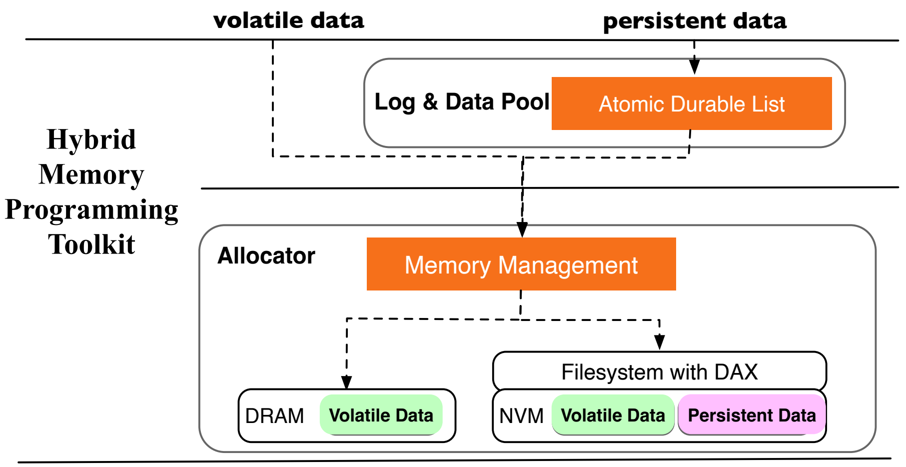
- Toolkit
  - ➢ Allocator; Log & Data pool
- Database Core
  - ➢ Support abundant models for compatibility
  - ➢ Database components



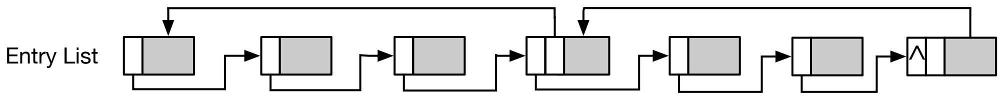
Toolkit

- **Allocator**
  - Manages both DRAM and NVM, and produces *malloc/free* style APIs.
  - Metadata is volatile
  - An allocation can be recovered.

- **Log & Data Pool**
  - *Stores all persistent data, which is organized by an atomic persistent list.*
  - Supports persistent and atomic append and delete.
  - Supports recovery.



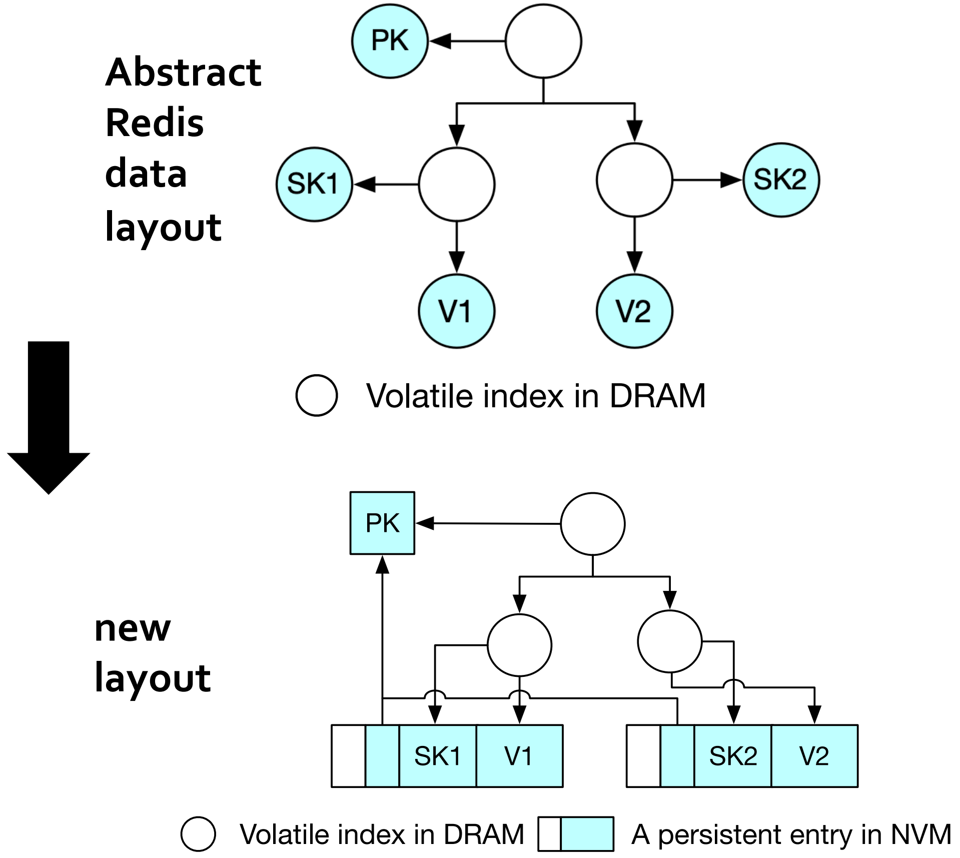
The structure of toolkit



The *log & data pool is a* list-organized structure.
Through scanning it, the allocations can be recovered.

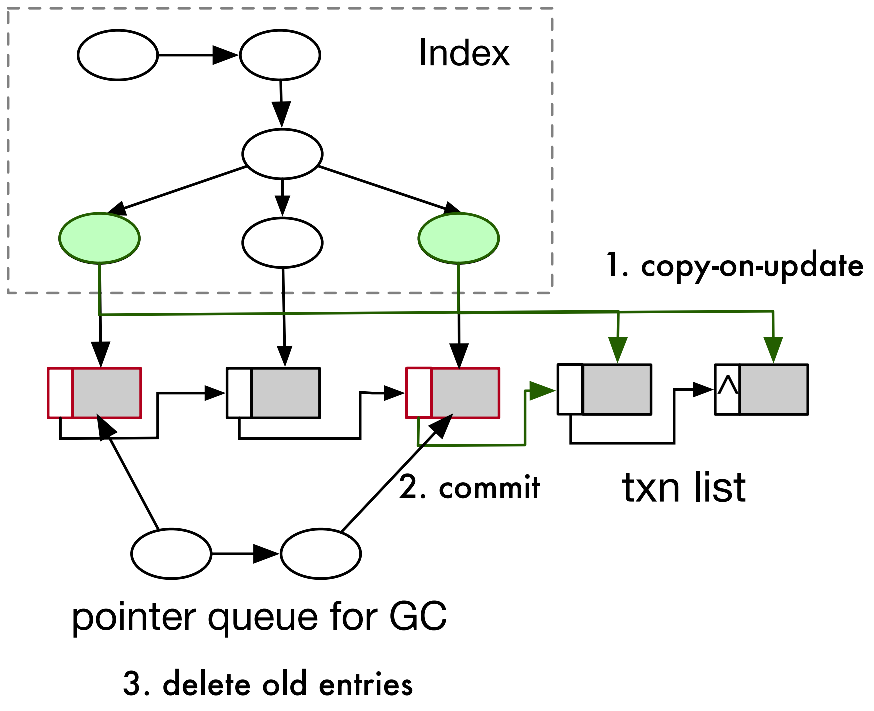
Database – Data Encode

- **Abundant model and indices**
- **The Encode Method**
  - ➢ Abstracted to KV/KKVs.
  - ➢ The key/value can be pointed by index as the original Redis.
  - ➢ The implementation of read operations remains intact.



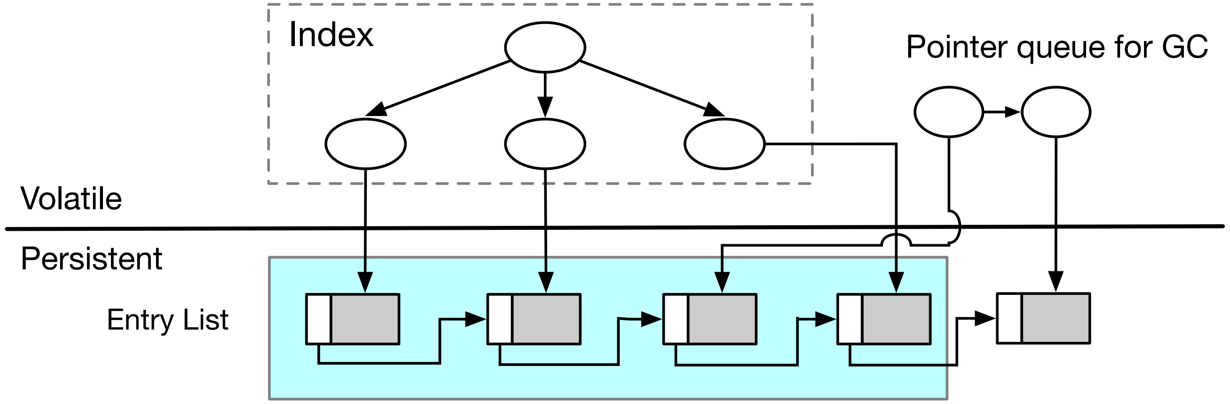
Database – User Write Operations

- Write operations generate an entry to serve as a redo log.
  - ➢ **Both Insert and Update operations** create a user data entry.
  - ➢ **Deletion** generates a tombstone entry.
  - ➢ **Take update as an example**
- Disaster Recovery
  - ➢ Sequentially redoes the log to reconstruct indices.



GC and Checkpoint

- **Entry deletion is done by the background GC thread.**
  - The deletion order should be right.
- **When taking a snapshot/checkpoint**
  - ➢ The GC thread protects the entries to be deleted.
  - ➢ Other procedures of checkpoint are the same as the original Redis'.



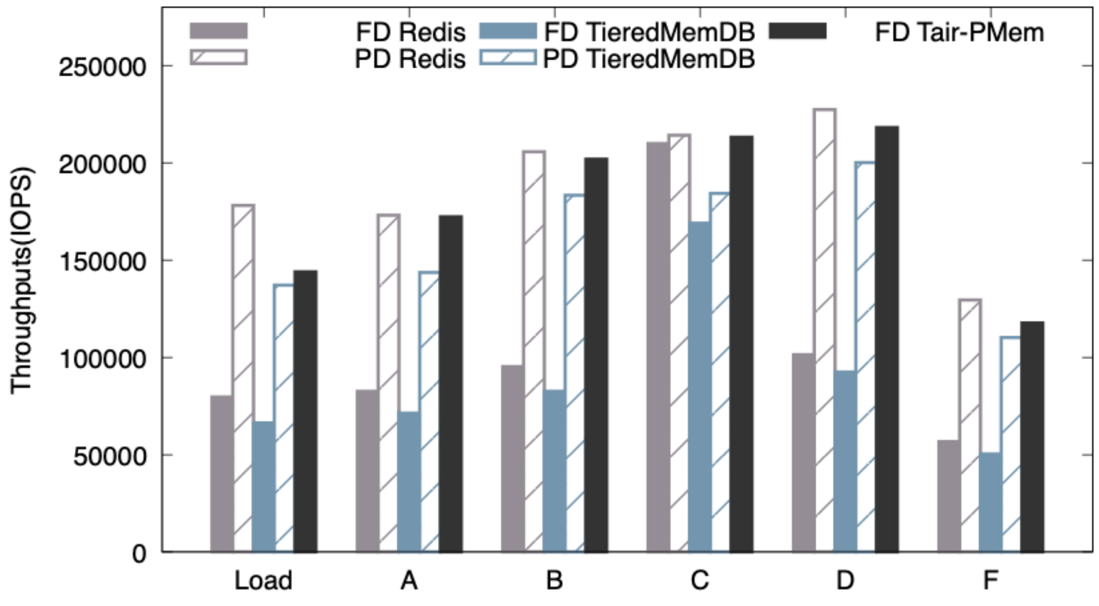
Programming Skills

- Breaking Large Values into Shards for COW
- Single Tombstone Entry When Possible
- Prefetching
- Pin frequently accessed index in DRAM

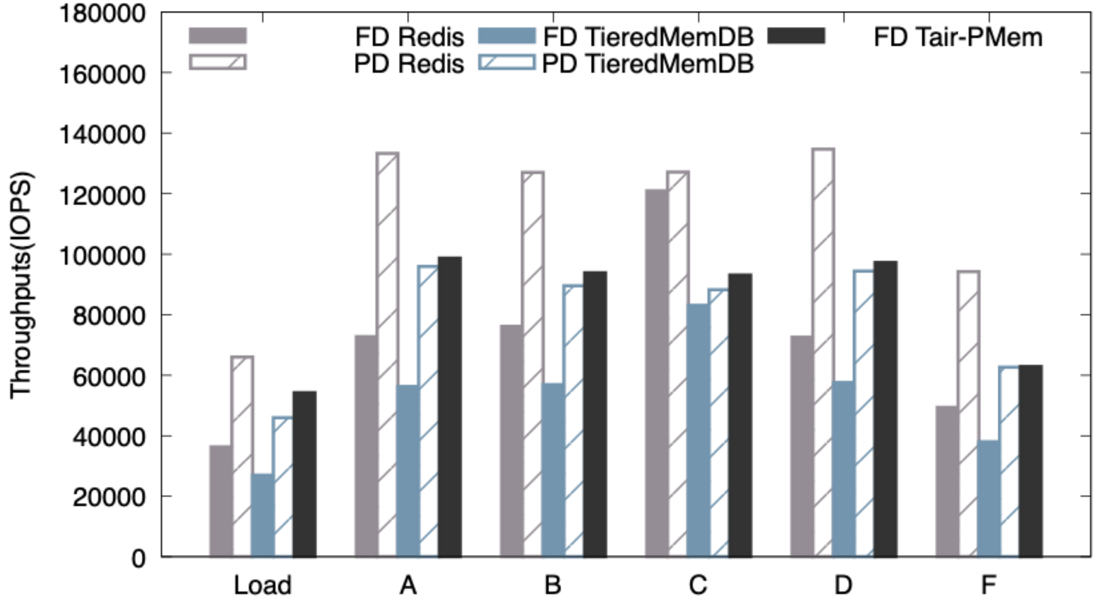
Outline

- Core Design Decisions
- The Database Architecture
- Evaluations

Throughputs



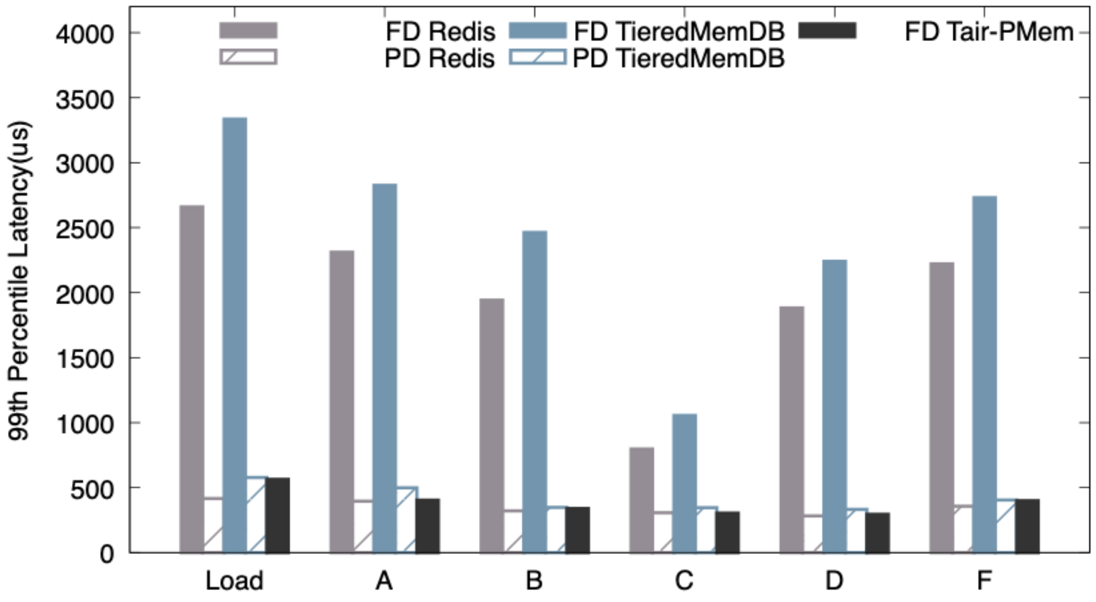
The throughputs of string model.



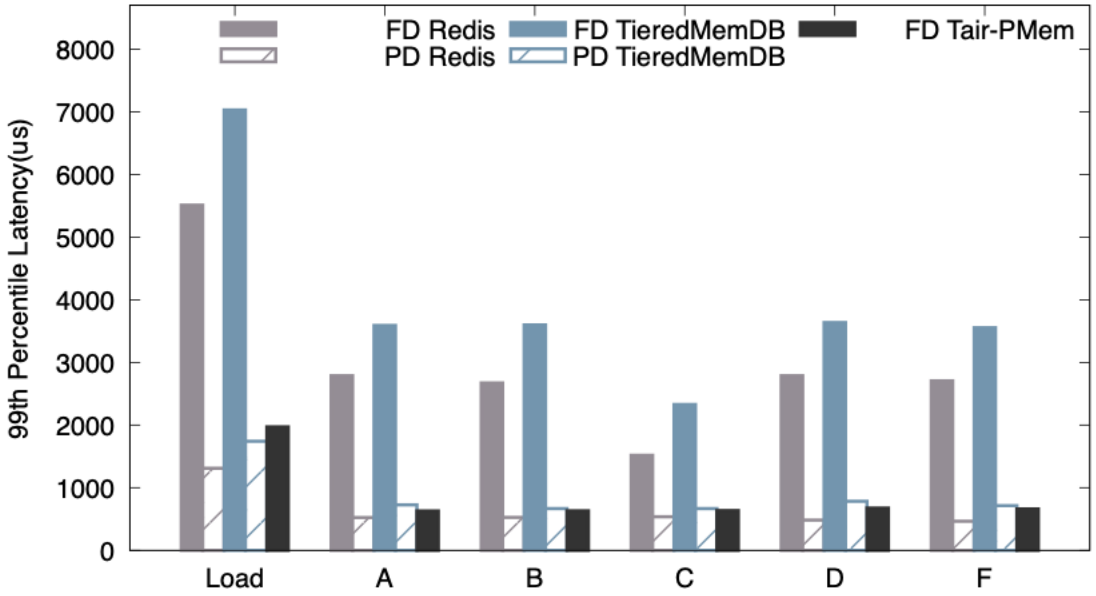
The throughputs of hash model.

Tair-PMem is better, compared to fully durable(FD) Redis,
Tair-PMem is comparable, compared to partially durable (PD) Redis,
Tair-PMem is always better, compared to TieredMemDB.

99 Percentile Latencies



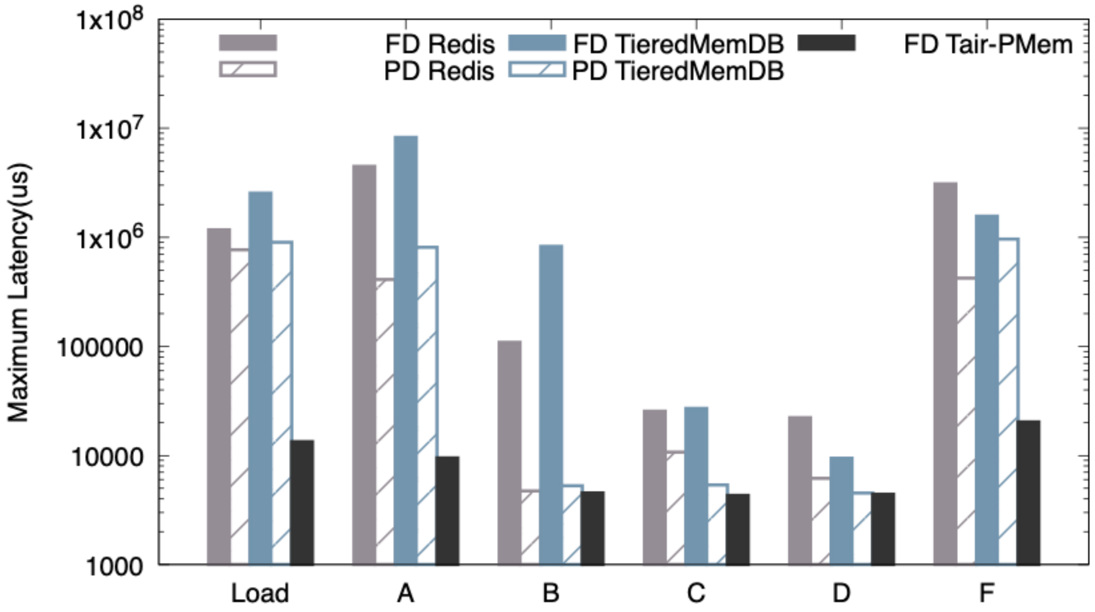
The 99 percentile latencies of string model.



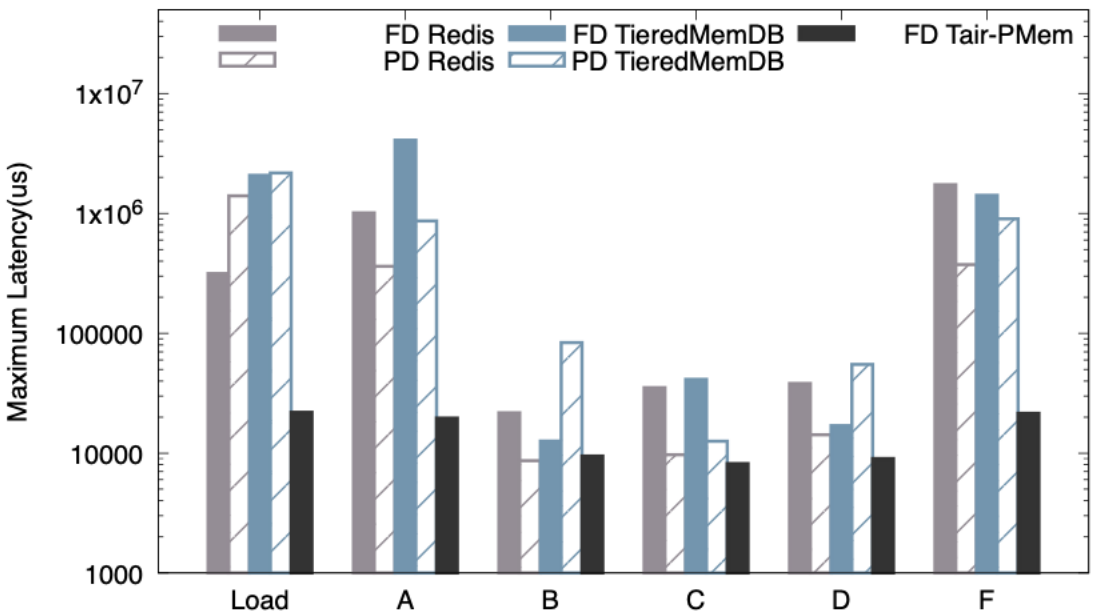
The 99 percentile latencies of hash model.

Much better 99 percentile latency due to no AOF writing.

Maximum Latencies



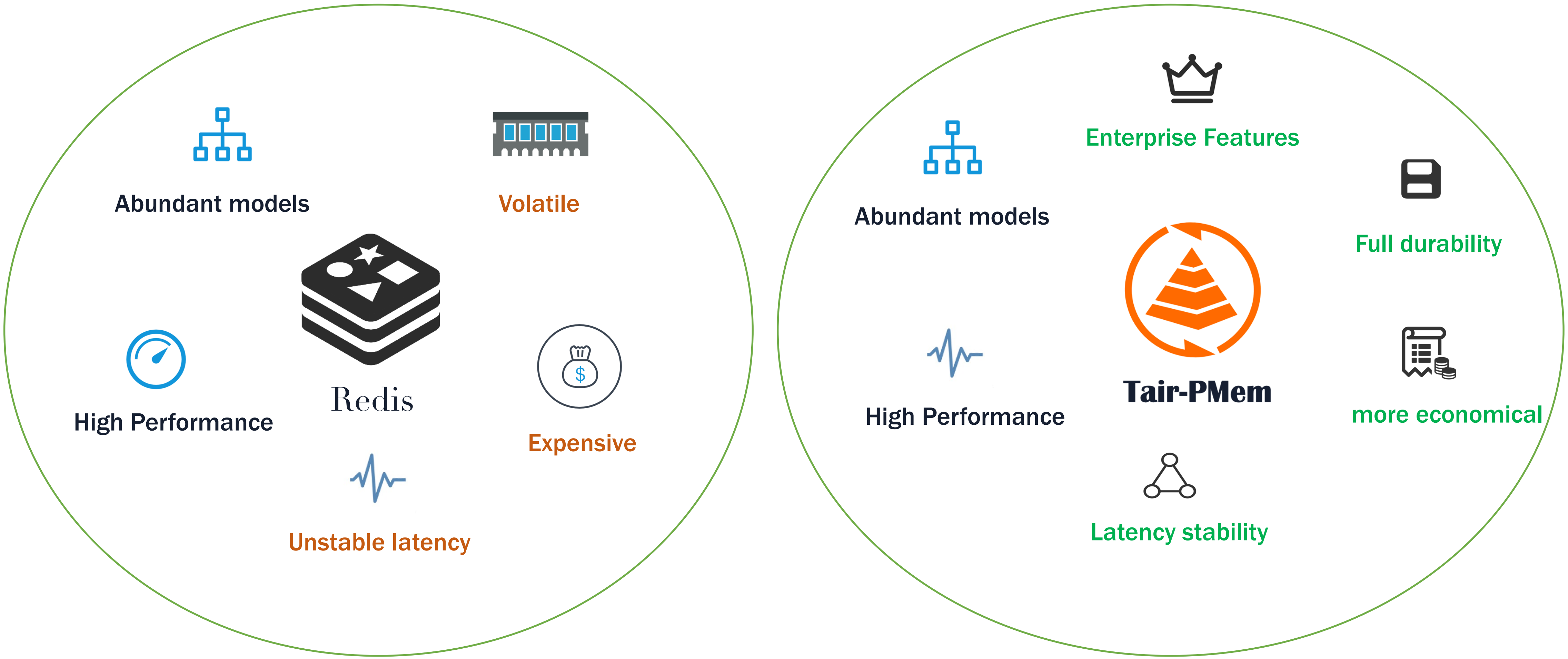
The maximum latencies of string model.



The maximum latencies of hash model.

Much more stable because of no AOF rewriting which incurs *fork* system call.

Conclusions



For More Information

[Tair-Pmem service on Alibaba Cloud]