Achieving High Throughput and Elasticity in a Larger-than-Memory Store

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One Slide Summary

Multi-core optimized single-node key-value stores are emerging

- ➔ **Very** high throughput ~**100 Million events/sec/server.** Ex: FASTER (SIGMOD'18)

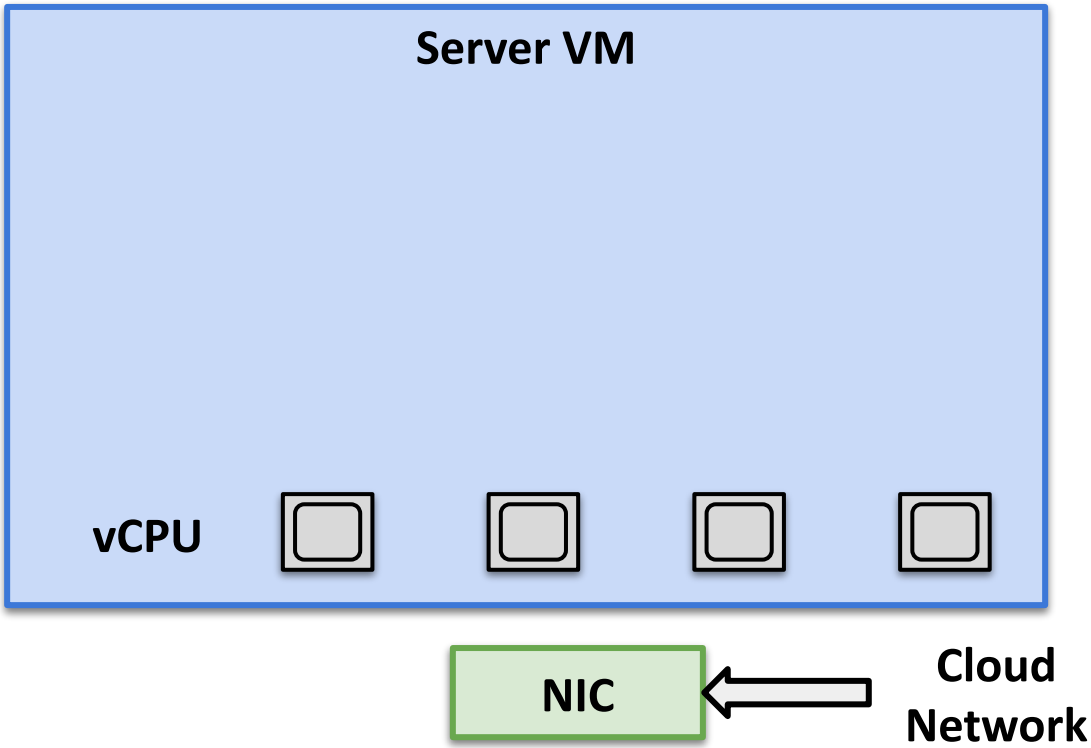
Can we retain such high throughput in the public cloud?

- ➔ **Saturate servers within hash index** → Avoid request dispatch and network bottlenecks
- ➔ **Workloads change, VMs fail** → Support reconfiguration while preserving throughput

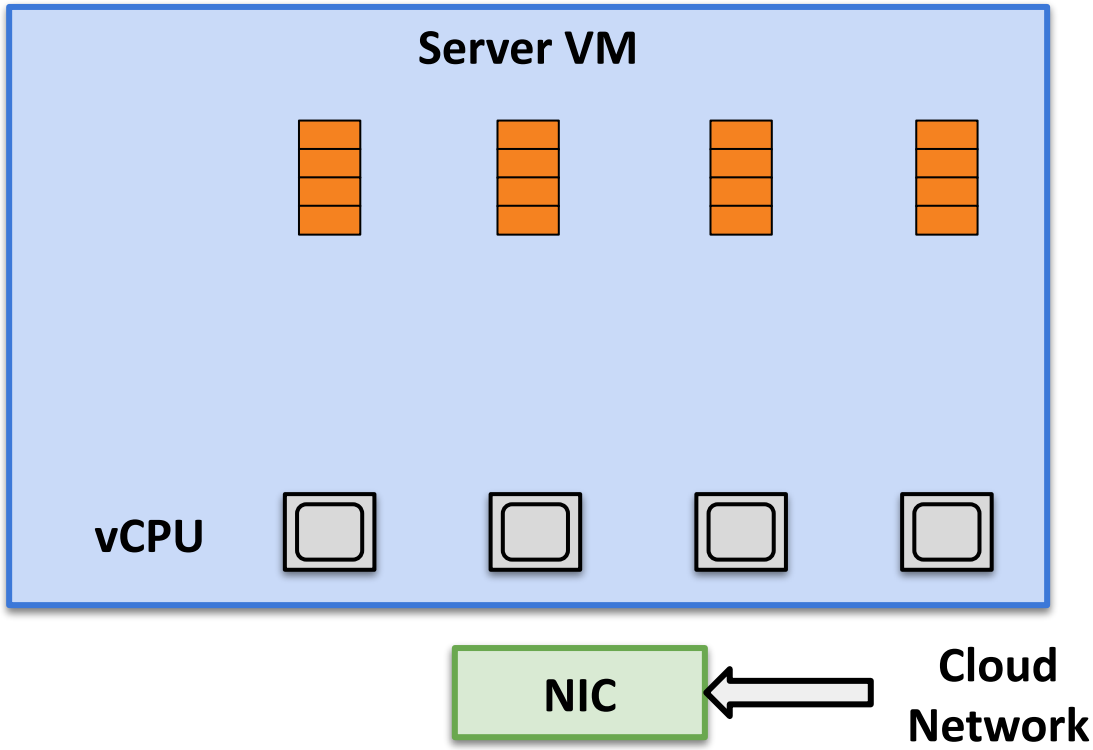
Shadowfax: Distributed key-value store built on FASTER

- ➔ **100 Million events/sec/VM on Azure**
- ➔ **80 Million events/sec/VM** during migration
- ➔ Spans DRAM, SSD and Cloud blob storage

Seastar: State-of-the-art Cloud Key-Value Store



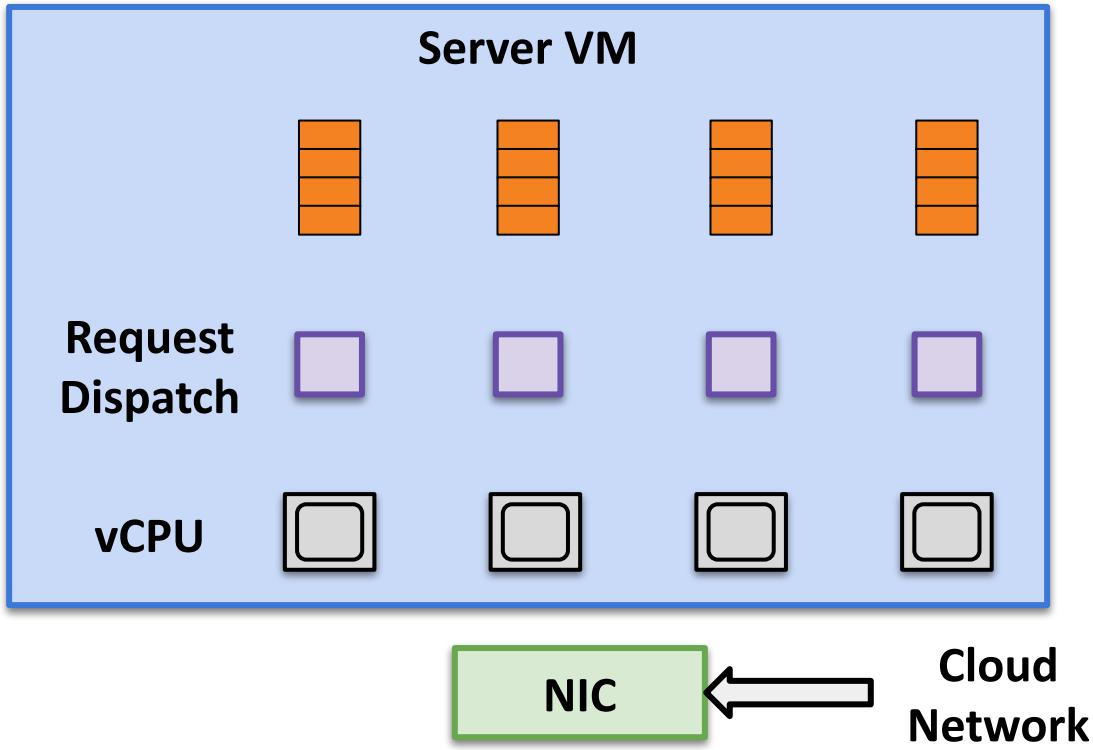
Seastar: Records Partitioned Across Cores



Hash partition records across vCPUs

Avoids synchronization on records

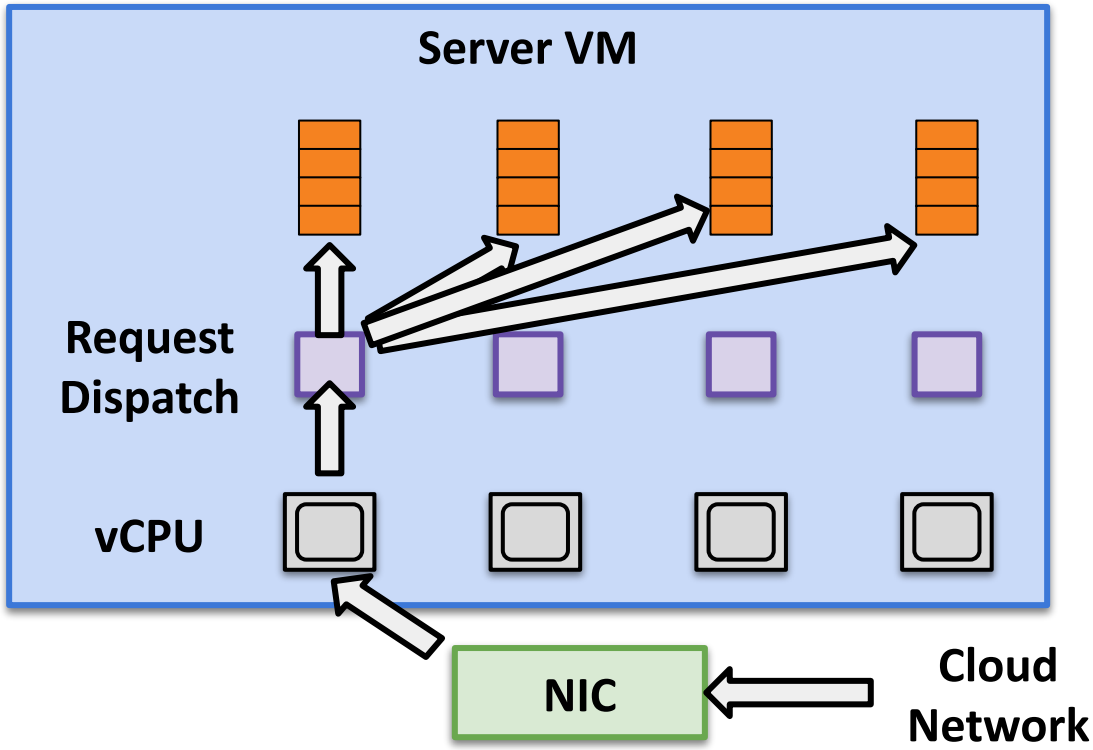
Seastar: Records Partitioned Across Cores



Dispatcher on every vCPU

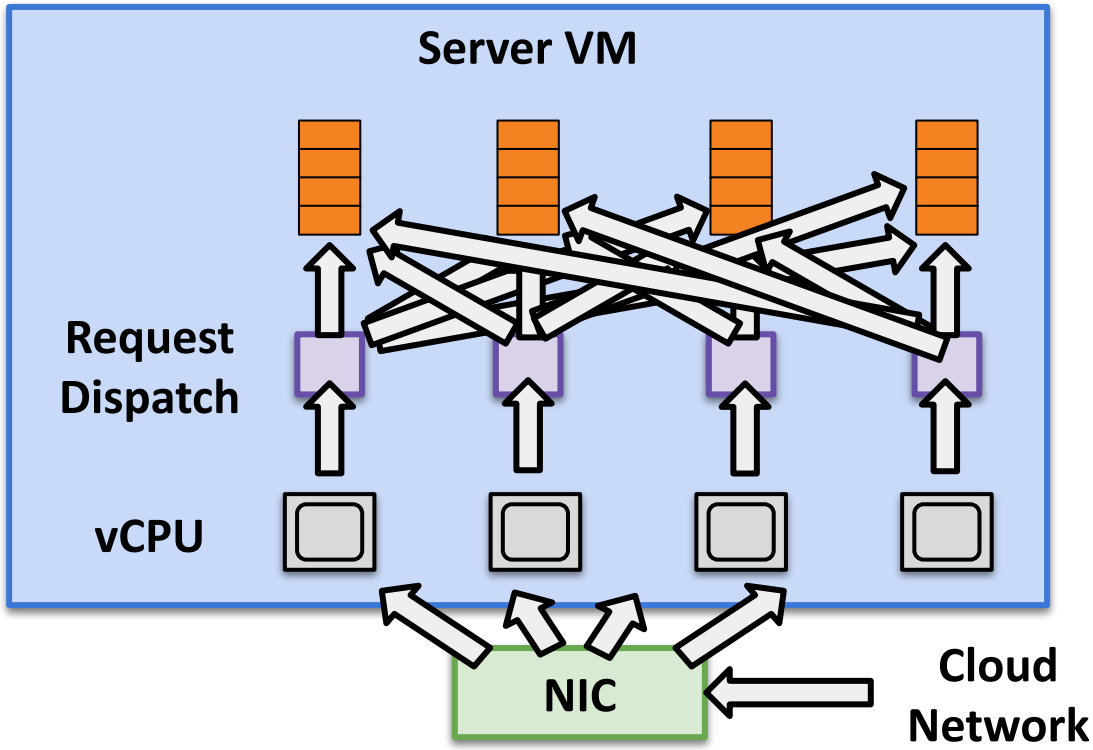
Each listens on different TCP port

Seastar: Requests Routed Within Server



Each dispatcher routes requests to correct partition

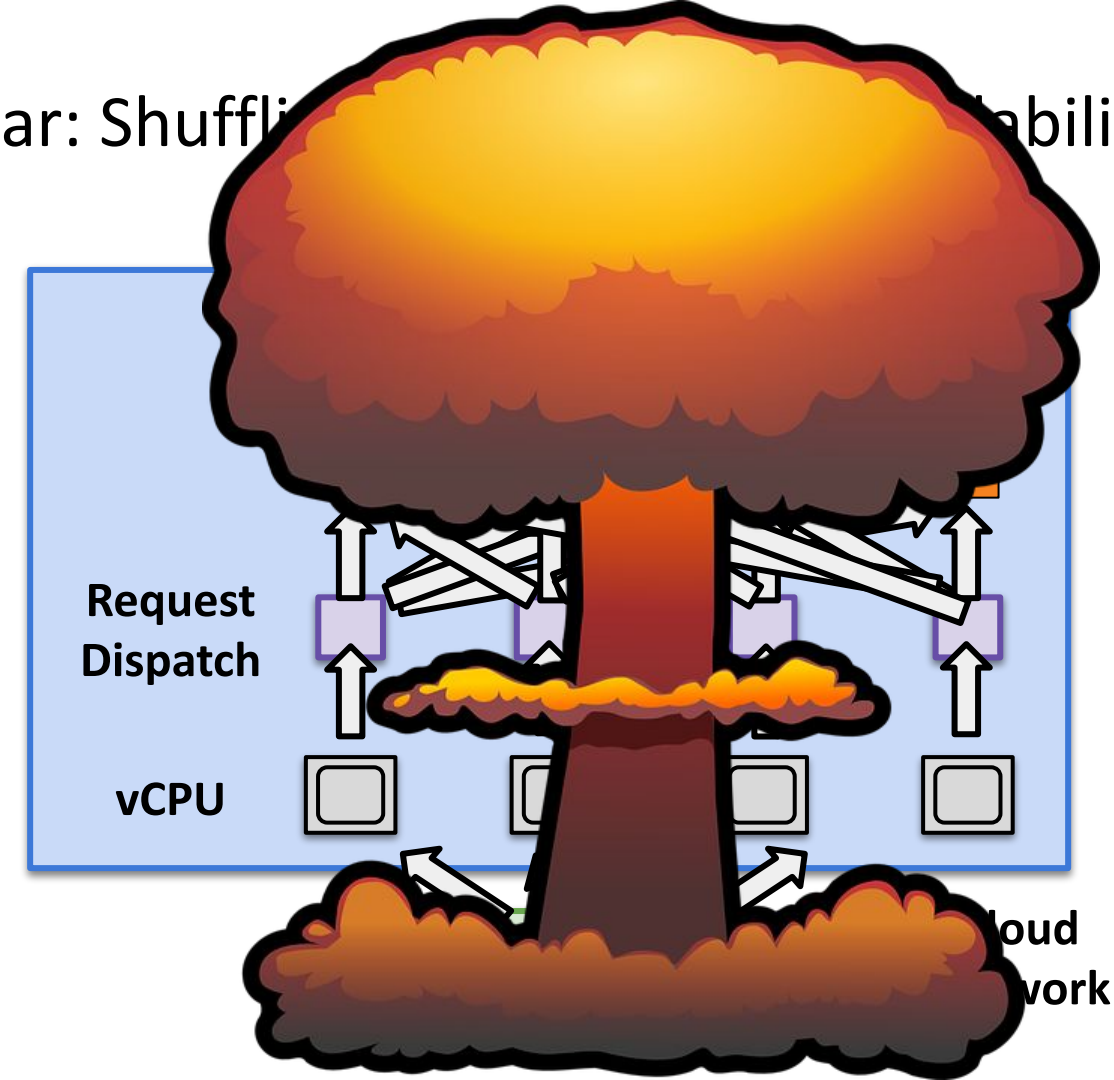
Seastar: Shuffling Requests Limits Scalability



Each dispatcher routes requests to correct partition

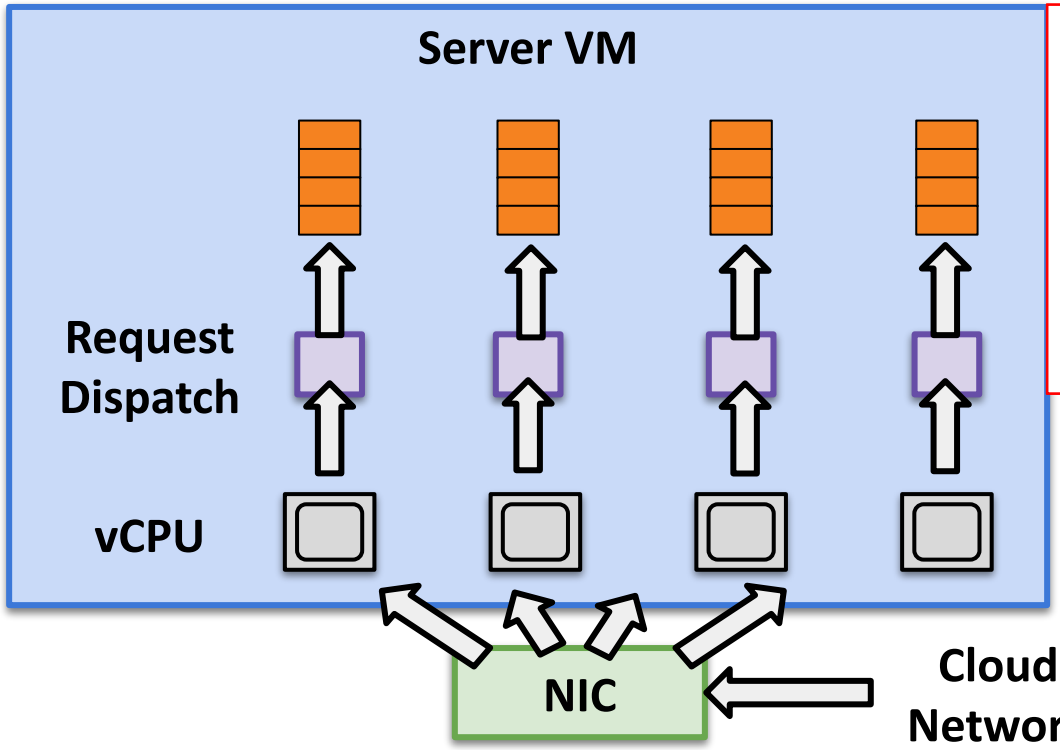
Expensive shuffle!

Seastar: Shuffli…ability



Doesn't scale across vCPUs

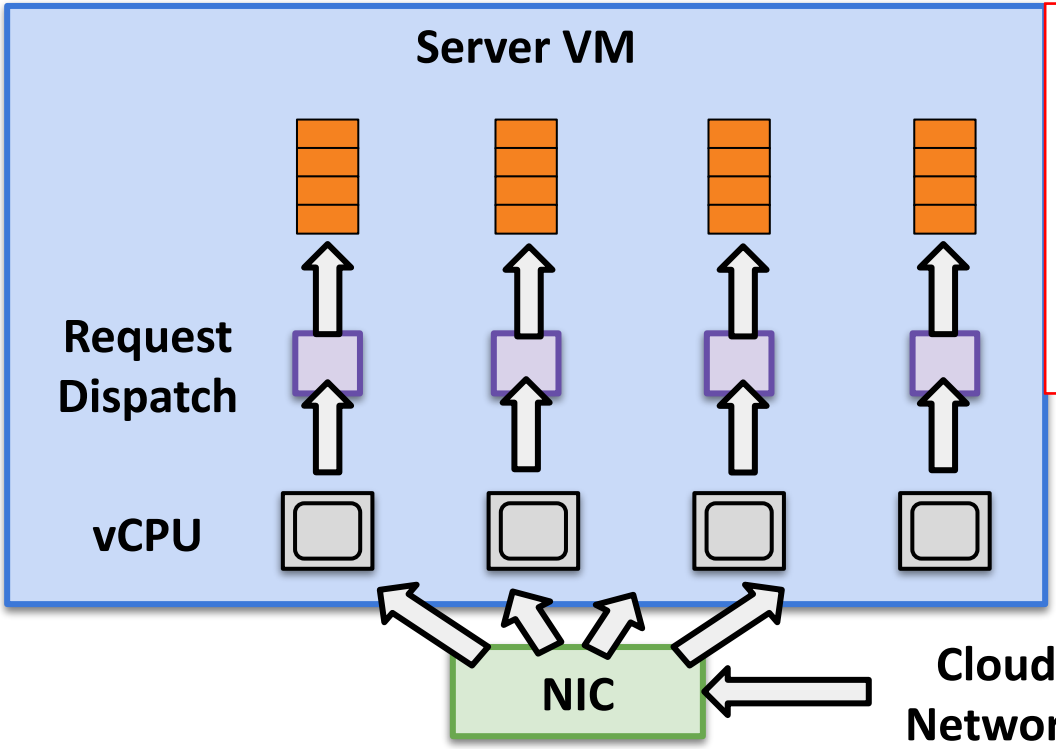
Seastar: Clients Could Route Requests Correctly



Clients could route to correct vCPU/owner

Quadratic connection state!

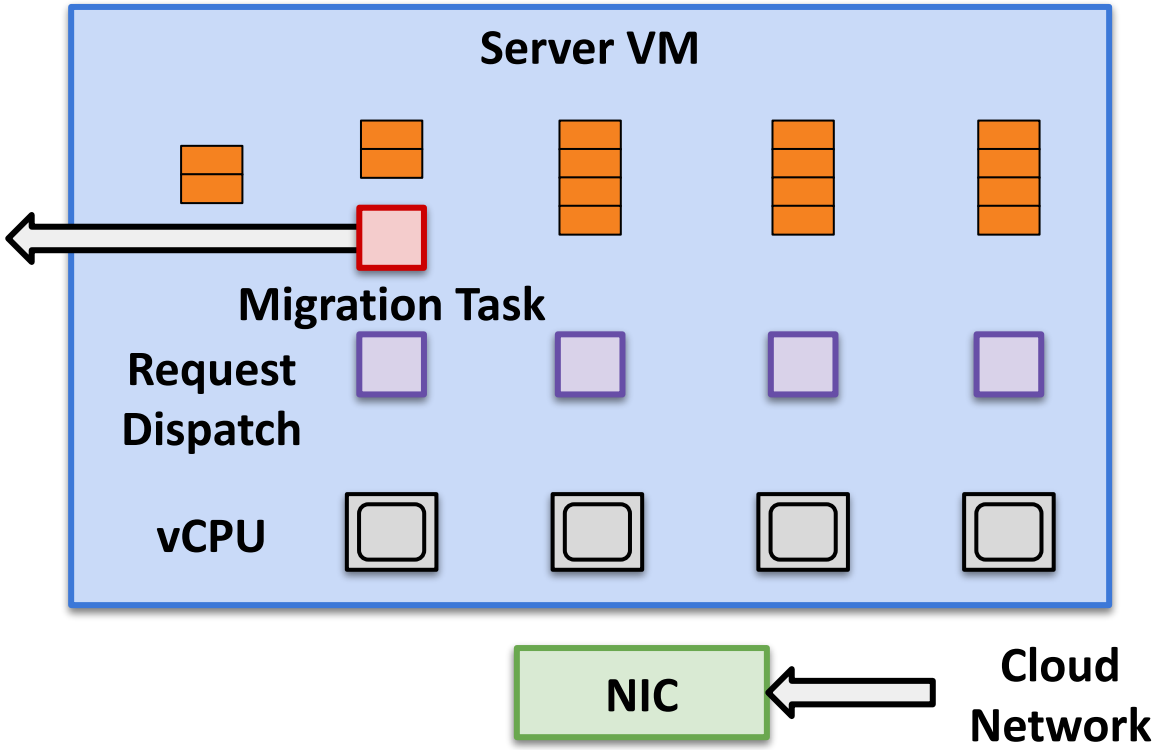
Seastar: Clients Could Route Requests Correctly



Clients could route to correct vCPU/owner

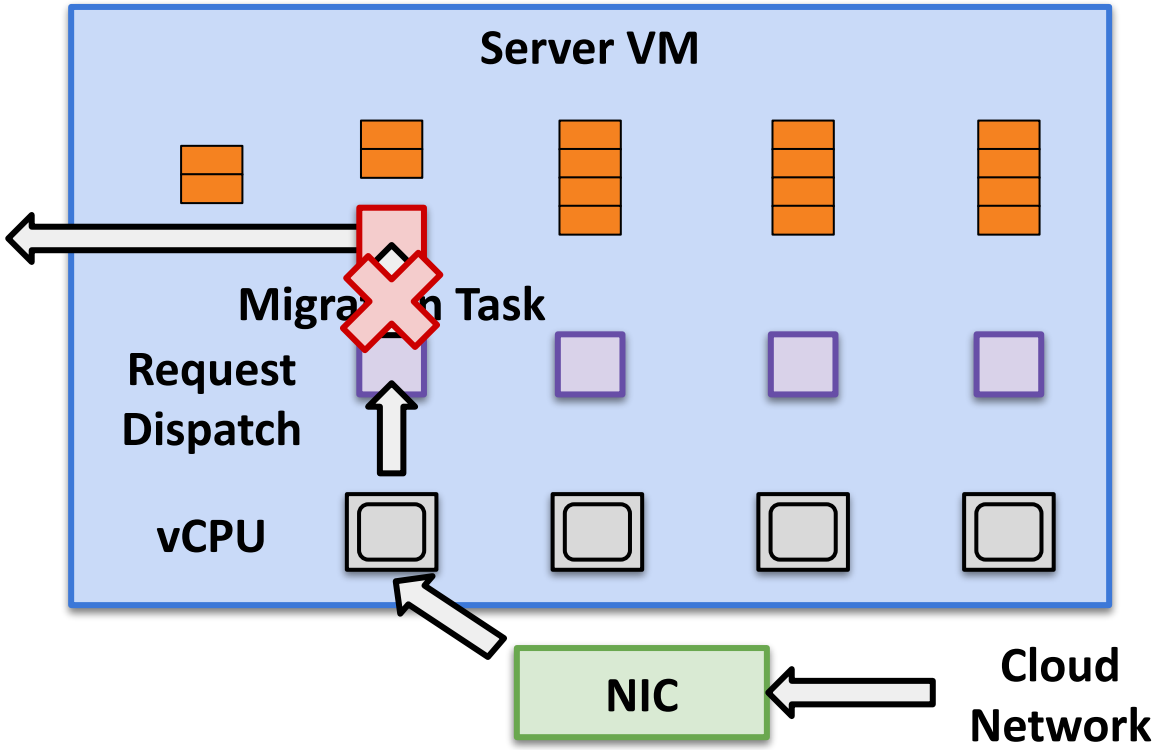
Shuffle requests at client!

Seastar: Migration Has To Be Single Threaded



Migration cannot be parallelized

Seastar: Head-of-line Blocking During Migration



Migration blocks requests on partition

Shadowfax: Design Overview

Partitioned Request Dispatch, Shared Data

- ➔ vCPUs share lock-free index → record synchronization handled by cache coherence
- ➔ Migration can be parallelized, does not block requests on hash ranges

End-to-End Asynchronous Clients

- ➔ Issue pipelined asynchronous batches of requests to amortize network overhead
- ➔ Good for workloads with inter-request independence. Ex: click counts, heartbeats etc.

Asynchronous Global Cuts

- ➔ Per server view numbers represent hash ranges owned by server
- ➔ Cores avoid coordination during migration ownership changes

Shadowfax: Design Overview

Scale-out and Hash Migration Protocol (Refer to paper!)

- ➔ Leverages asynchronous global cuts; is parallel and deadlock-free
- ➔ Fault-tolerant, can be cancelled; can recover if servers crash

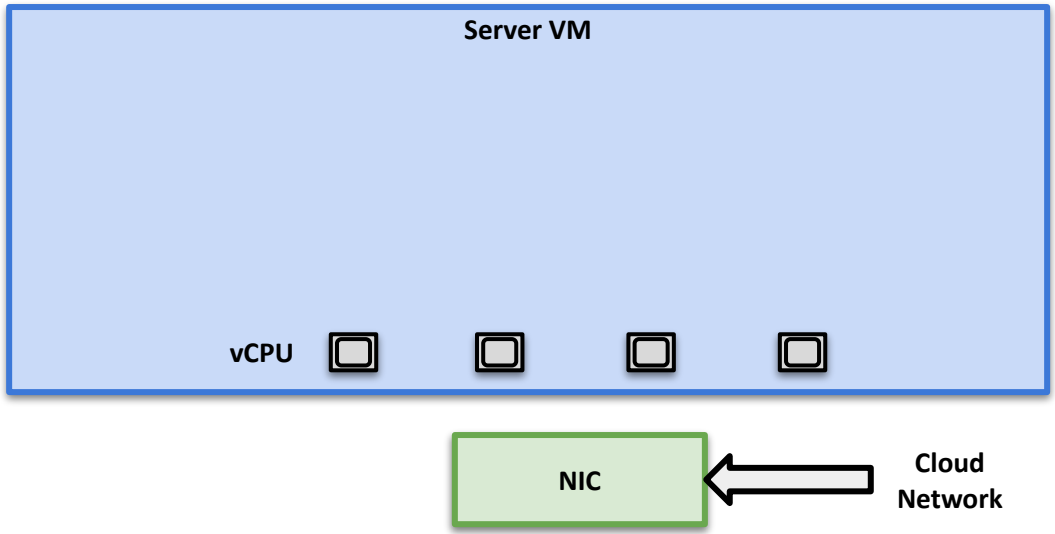
Spans Main-memory, Local SSD, and Shared Remote Storage

- ➔ During migration, only transfer (hot) data in main-memory
- ➔ Transfer pointers to rest (cold)
- ➔ Lazily clean these pointers during compaction (refer to paper!)

Shadowfax: Partitioned Request Dispatch Shared Data

Problem: **Avoid cross-core coordination at server**

Solution: **Offload all coordination to hardware cache-coherence protocol**



Shared memory is good for skew

Can serve hot records in parallel

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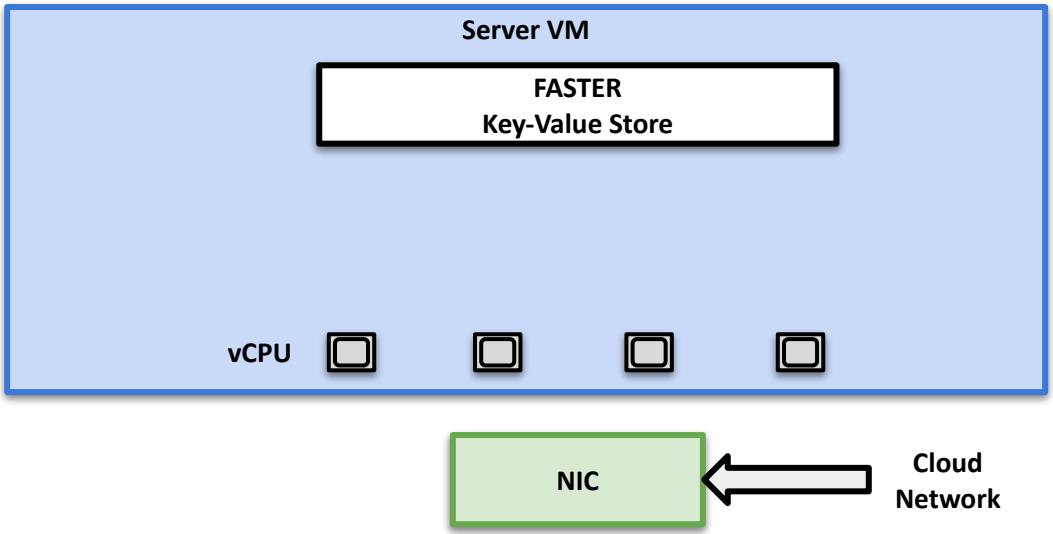


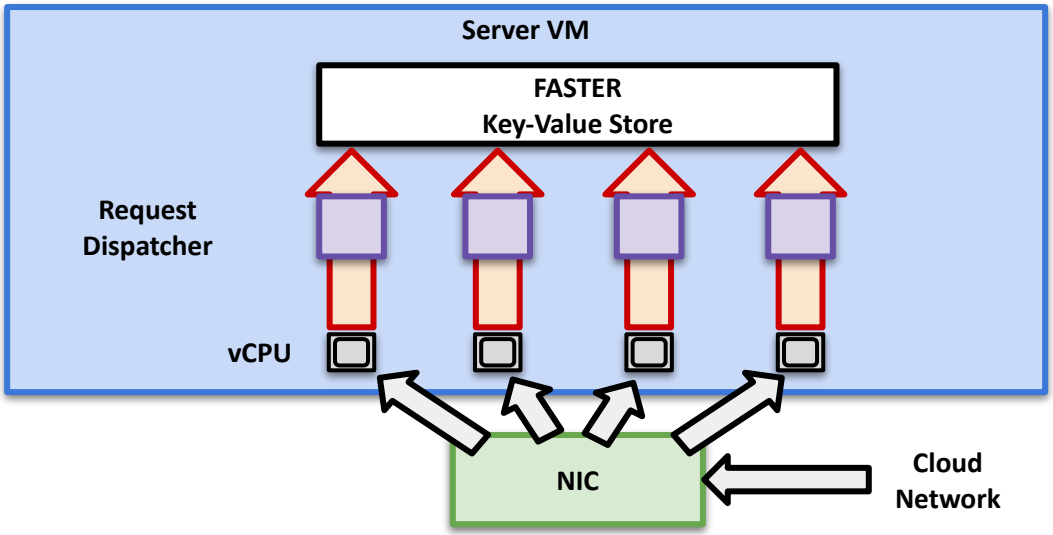
Lock-free index

Record synch happens at cache-coherence protocol (hw)

Shadowfax: Partitioned Request Dispatch Shared Data

Problem: **Multi-core request processing requires cross-core coordination**

Solution: **Offload all coordination to hardware cache-coherence protocol**



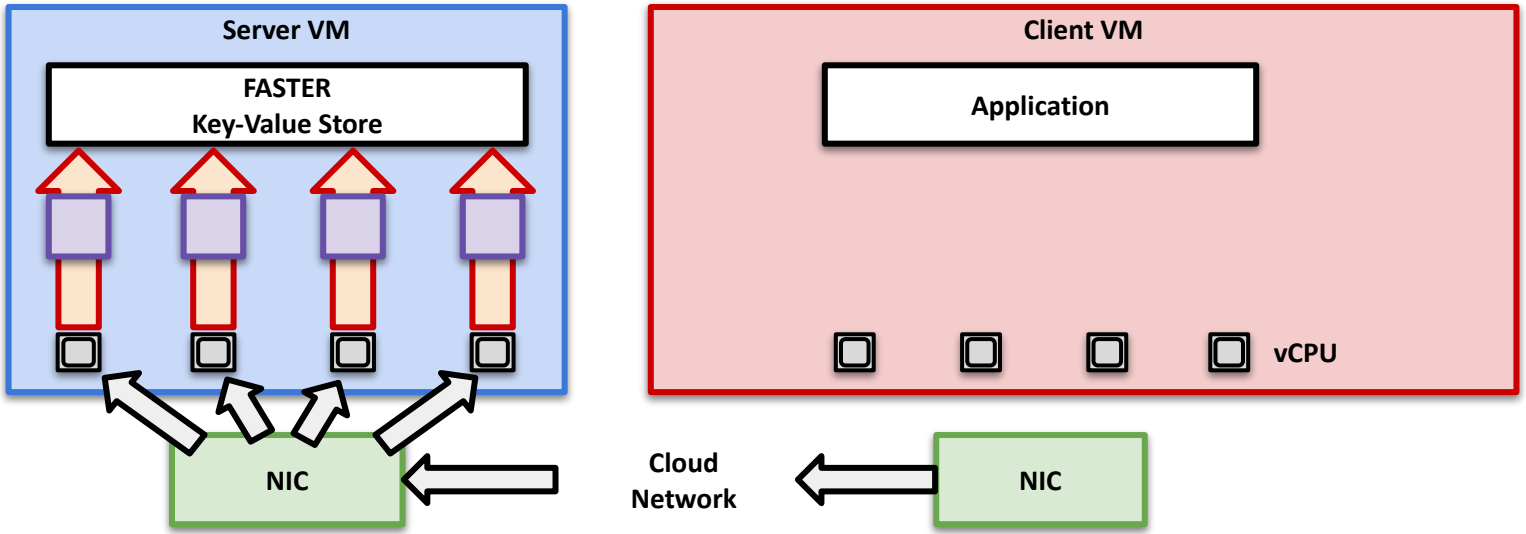
Partition request dispatch

Each dispatcher listens on separate TCP port

Shadowfax: Partitioned Request Dispatch Shared Data

Problem: **Keep servers saturated at index, not network or dispatch**

Solution: **Asynchronous client library, transparent network acceleration**



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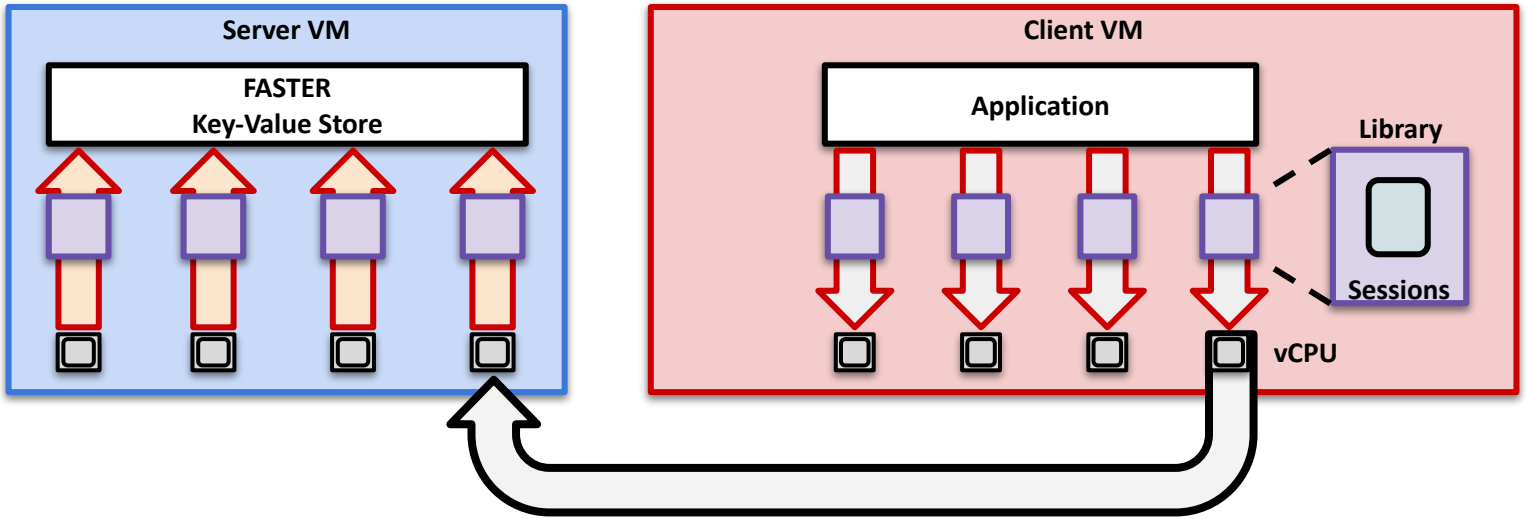

Client vCPUs open *"sessions"* to server vCPUs

Shadowfax: Partitioned Request Dispatch Shared Data

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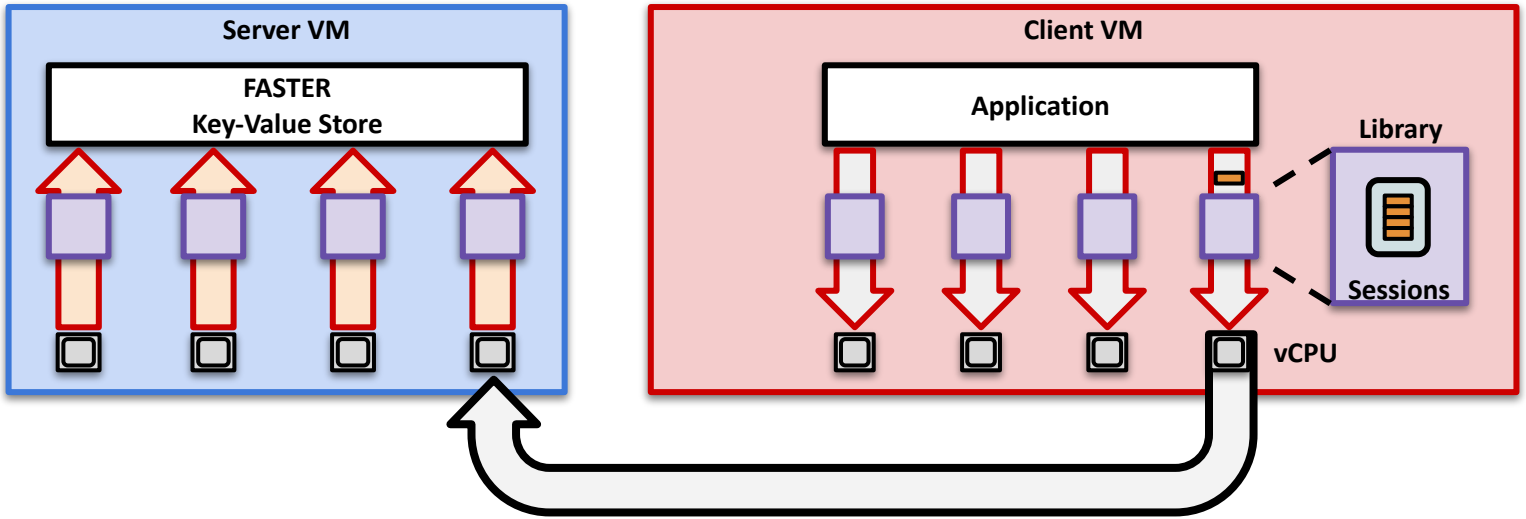

Requests are async

Enqueued in session buffers

Shadowfax: Partitioned Request Dispatch Shared Data

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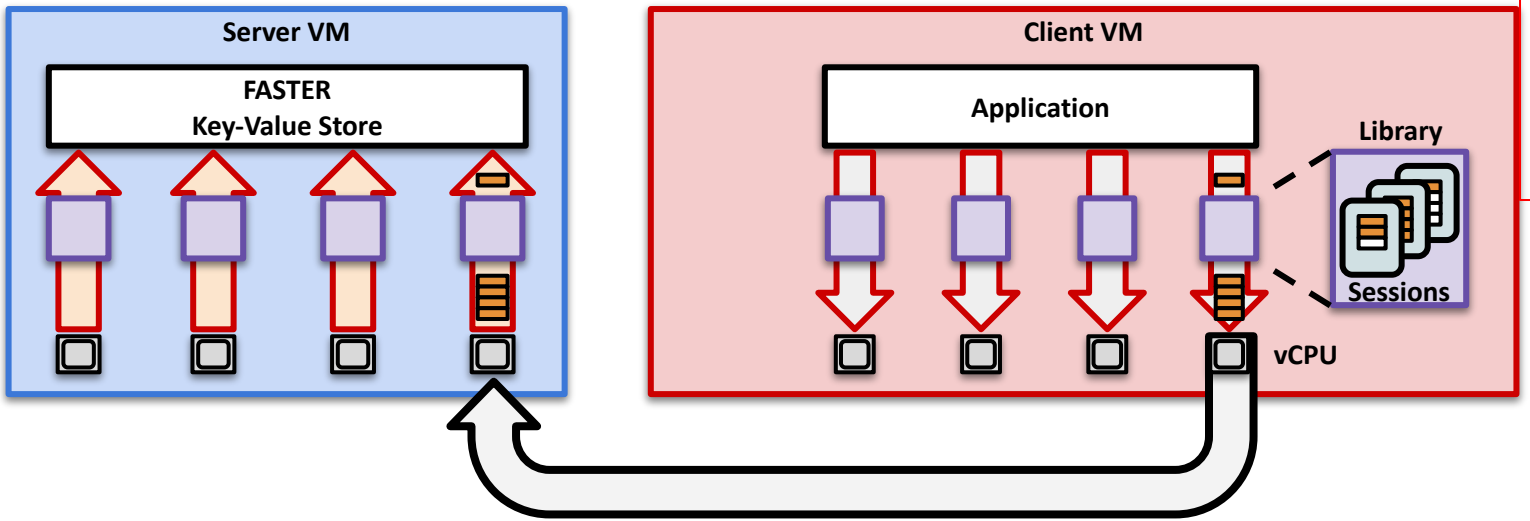

Pipelined batches are transmitted asynchronously

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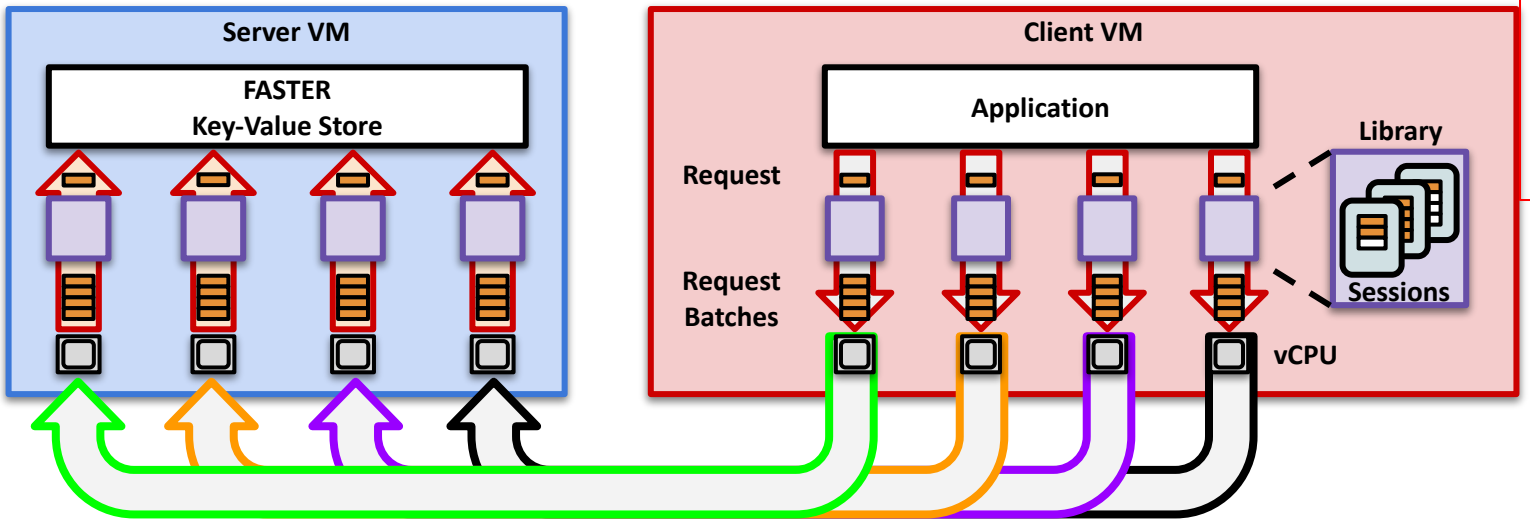

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Shadowfax: Transparent Cloud Acceleration

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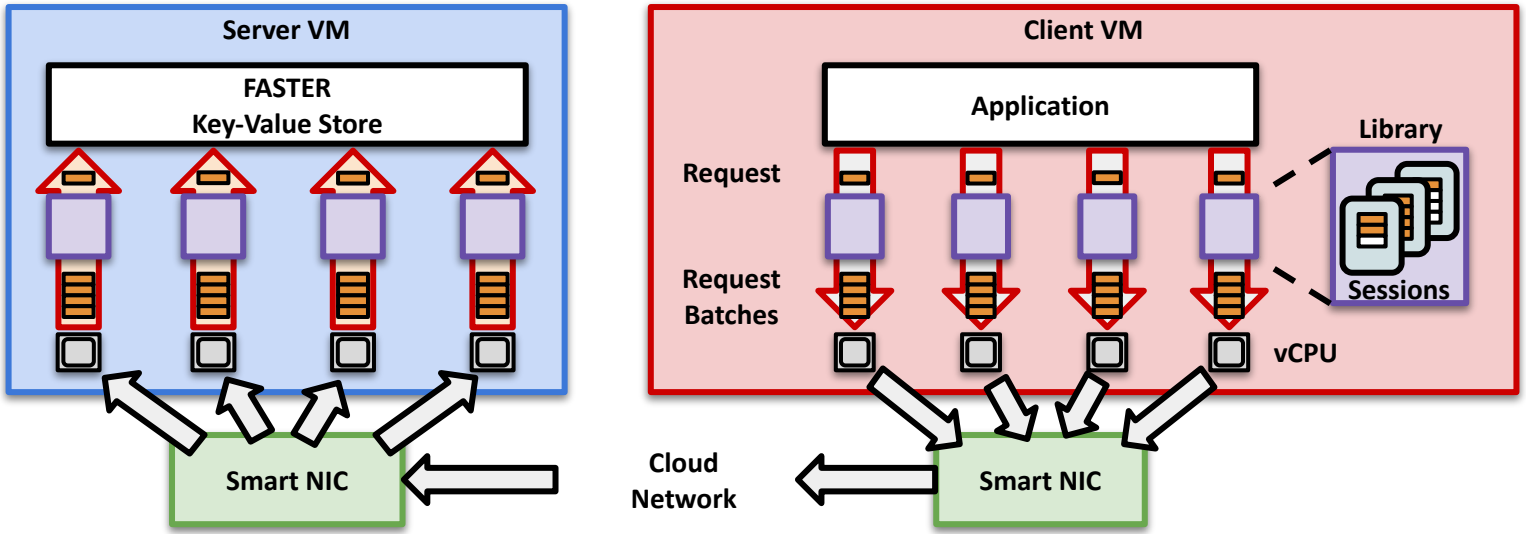
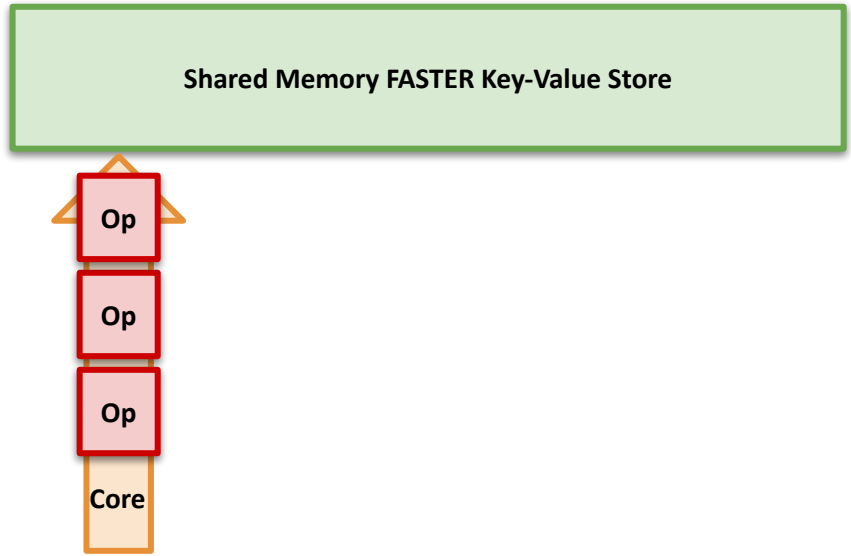


Hardware accelerated transport (TCP & Infrc)

Shadowfax: Asynchronous Global Cuts

Problem: Avoid cross-core coordination during migration

Solution: Server and client cores observe ownership change independently



Migration changes server's ownership
"View change"

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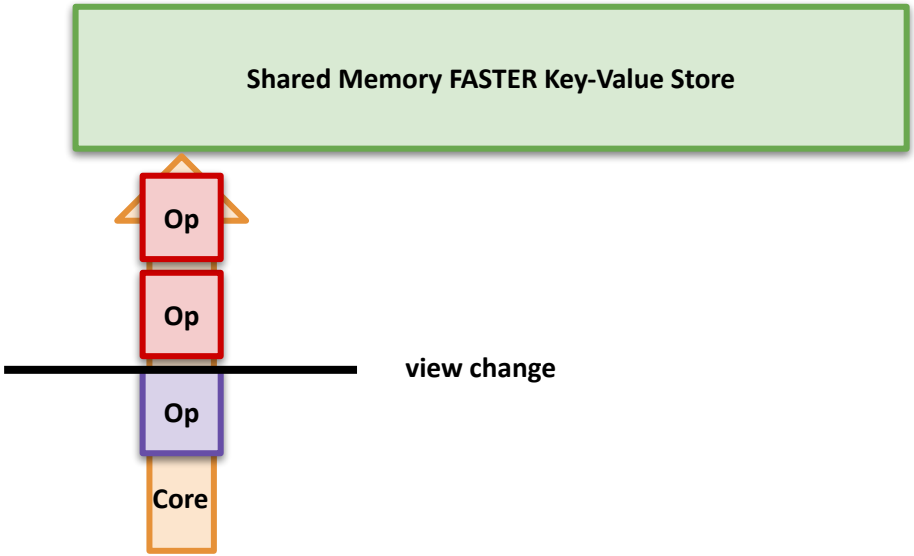

Retransmit operations after view change to new owner

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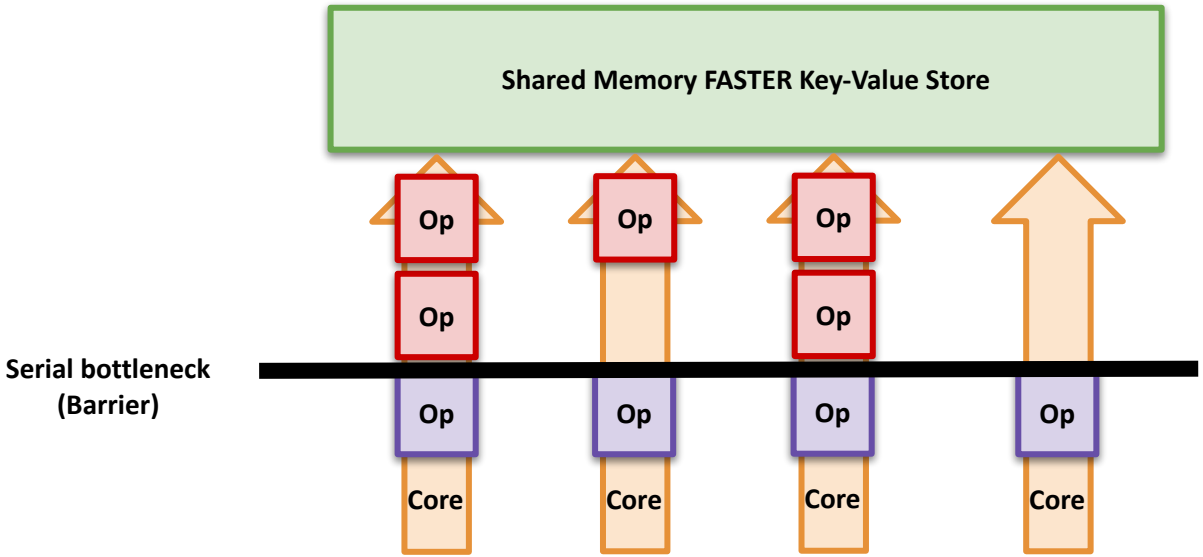

View change can become a serial bottleneck

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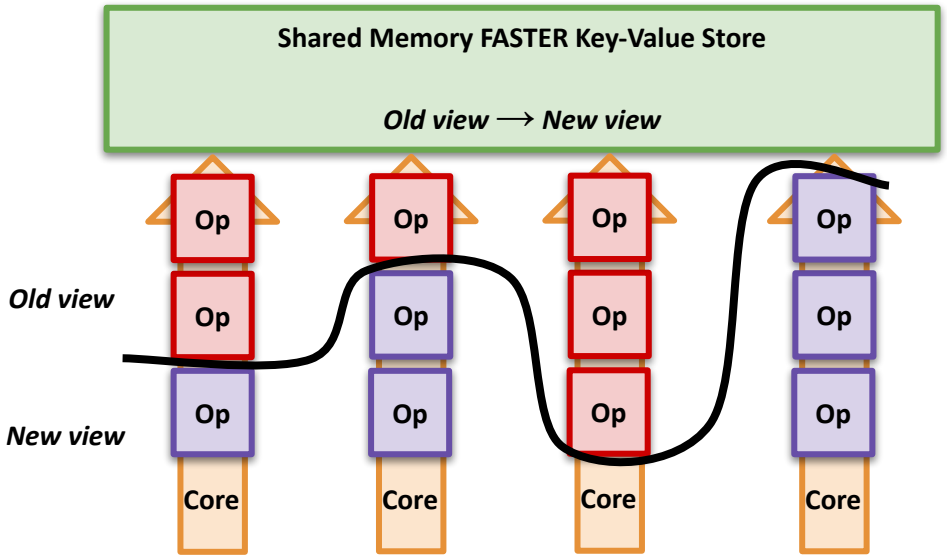

Each core observes change independently
"Async Cut"

Shadowfax: Asynchronous Global Cuts

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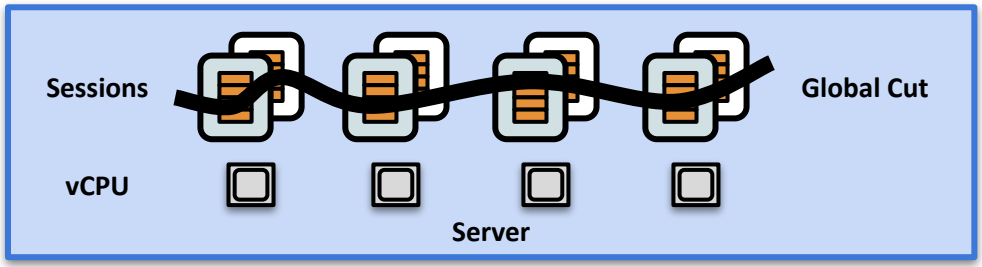
Async cut becomes *"global cut"* across sessions



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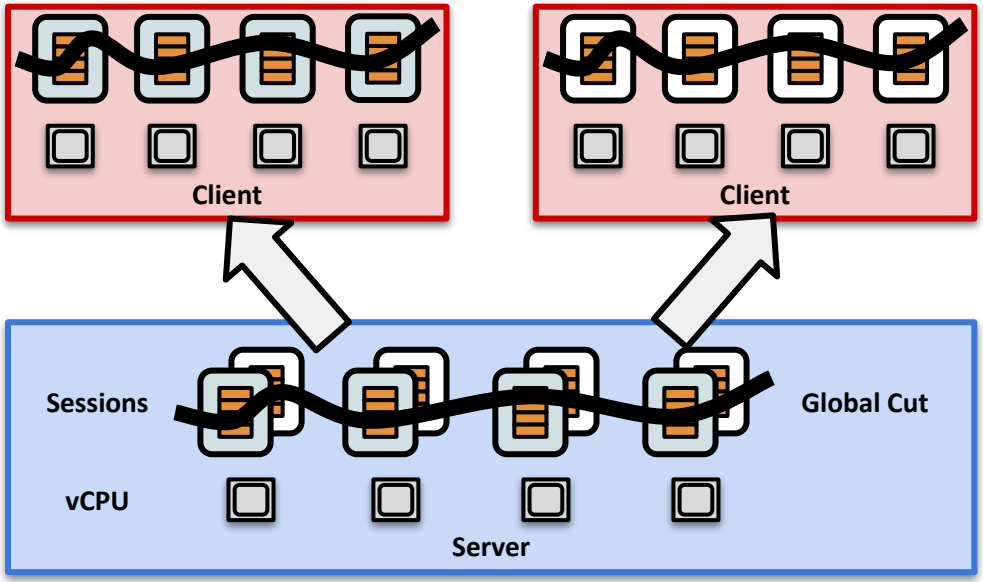
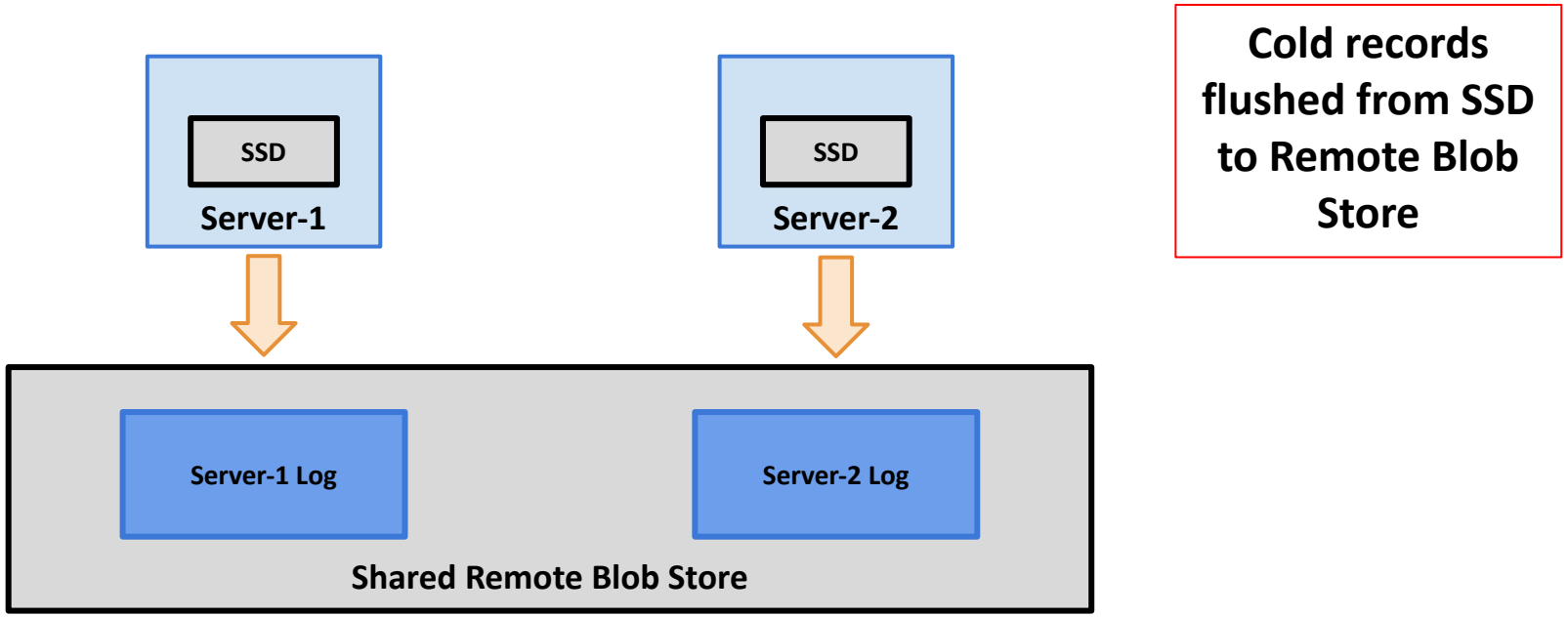


Global cut pushed to clients

Shadowfax: Indirection Records

Problem: Migrating records on SSD can slow down reconfiguration

Solution: Use shared remote tier to restrict migration to main memory



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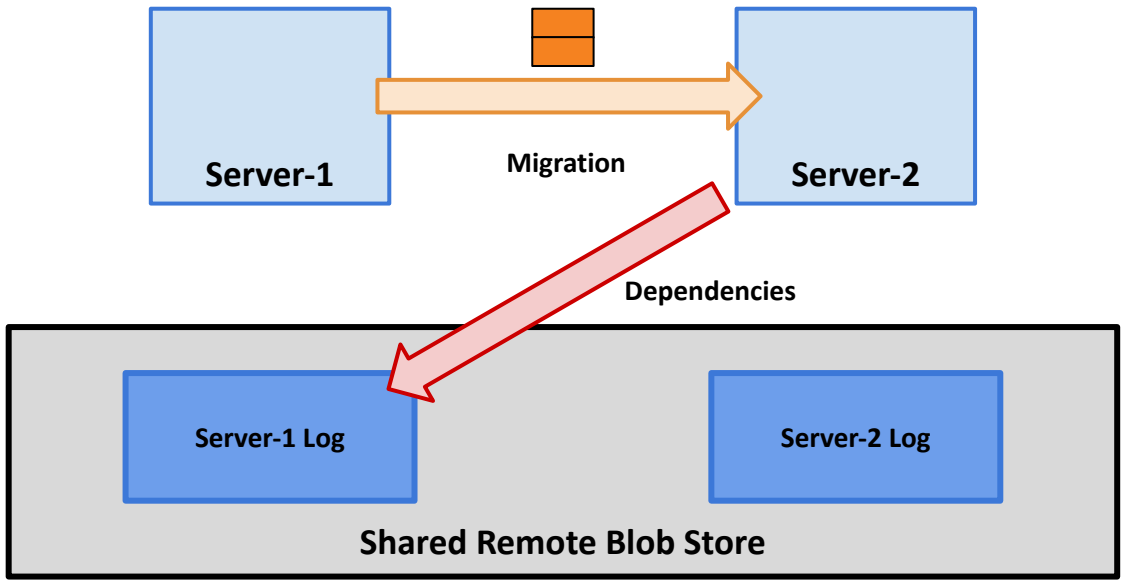
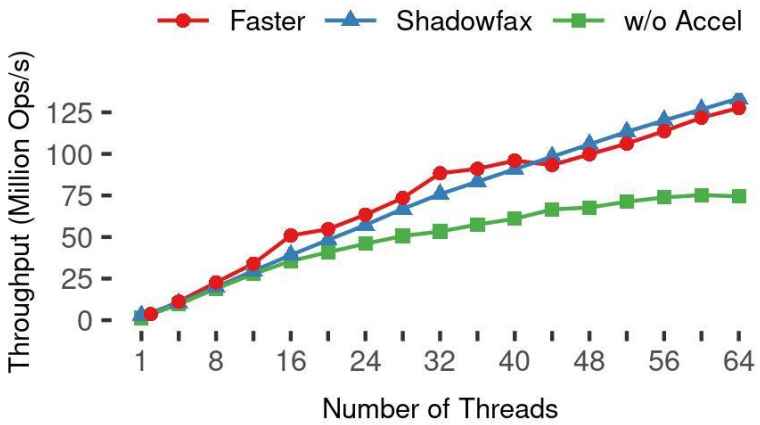


Migrate pointers to shared layer

Lazily cleaned up

Performance of Shadowfax

YCSB-F (Read-Modify-Writes, Benchmark Ingest of Events), 250 Million objects



Saturates server at Index

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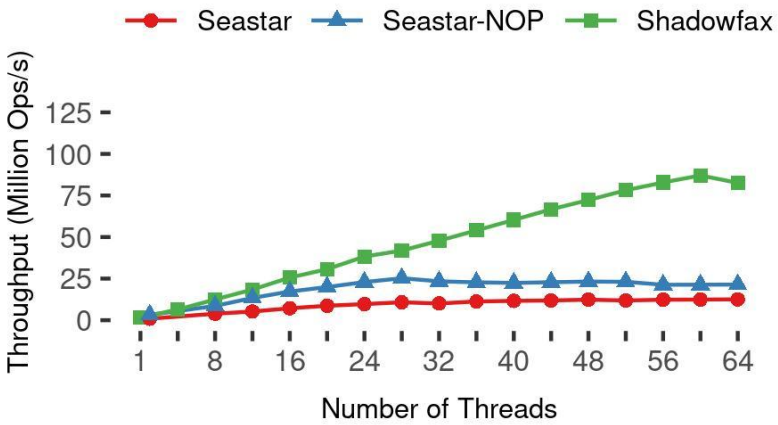

8.5x state-of-the-art

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