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Mako: A Low-Pause, High-Throughput Evacuating Collector for Memory-Disaggregated Datacenters

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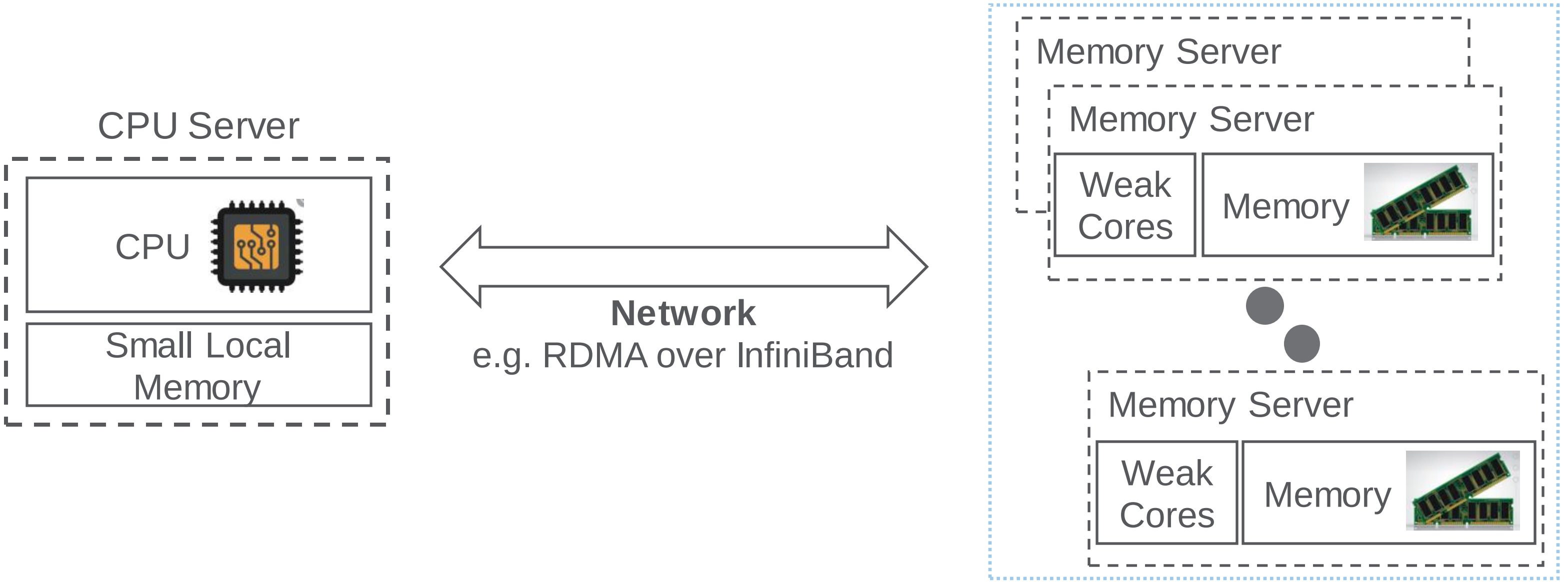
Australian National University

Memory Capacity Bottleneck in Datacenters

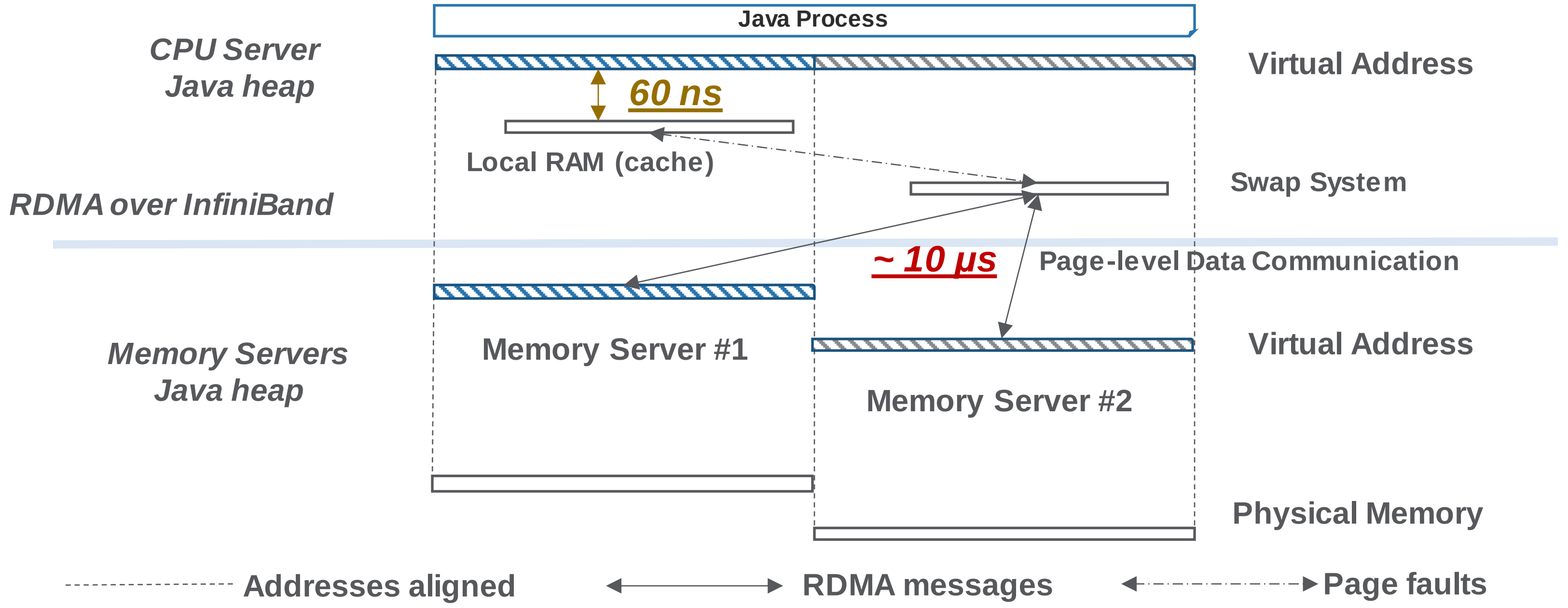
Growing imbalance between processor computation and memory capacity

Memory underutilization in datacenters

Memory Disaggregation



Java Heap Structure



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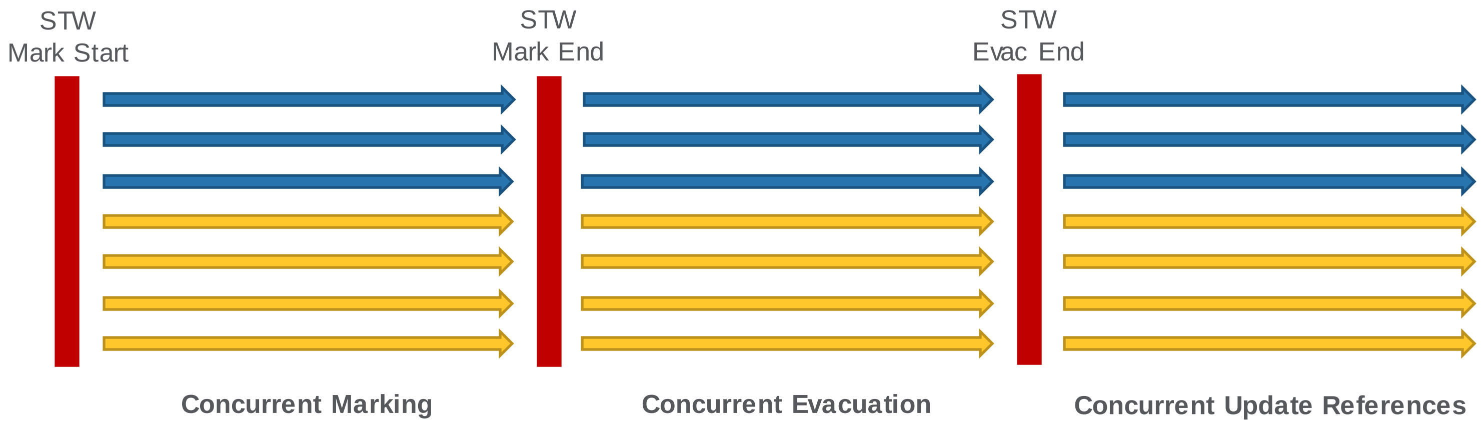
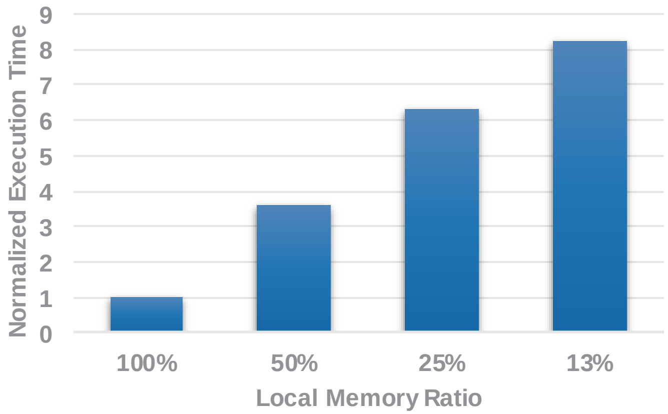
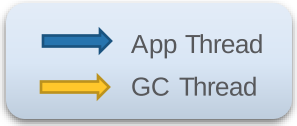
Concurrent GC







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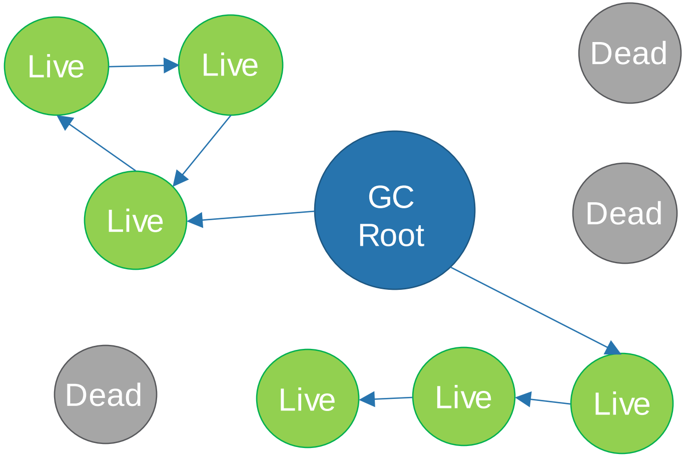
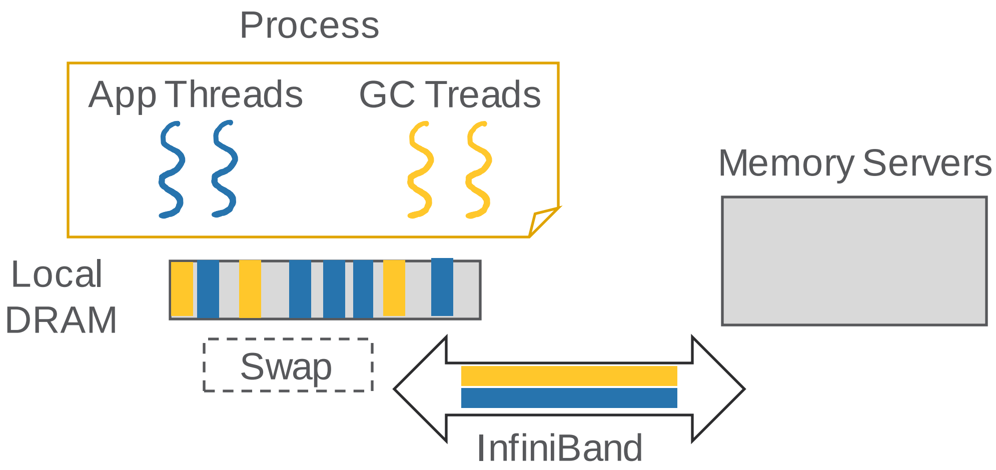
Concurrent GC

No Locality



Resource Contention



Can we move concurrent marking and evacuation to memory servers?

Can we move concurrent marking and evacuation to memory servers?

Reduced Interference

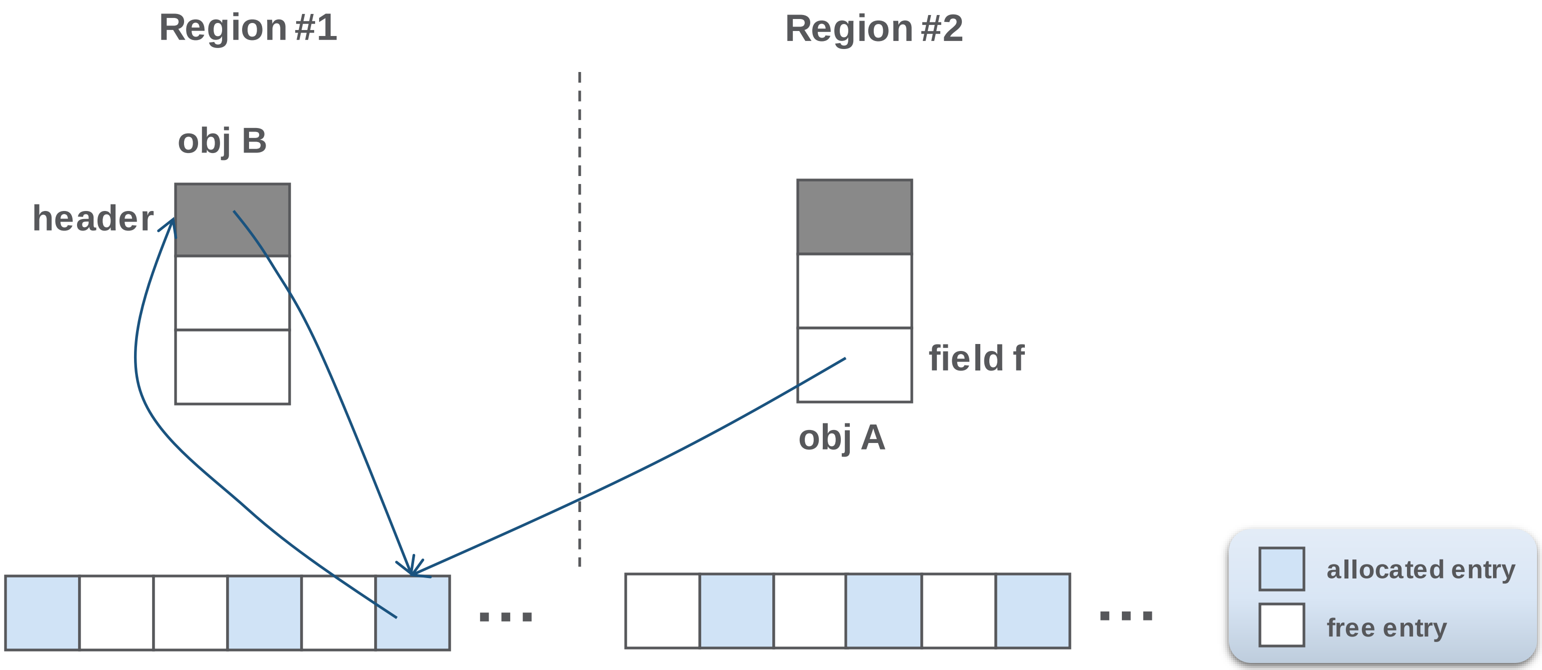
Near-data Computing

Challenges

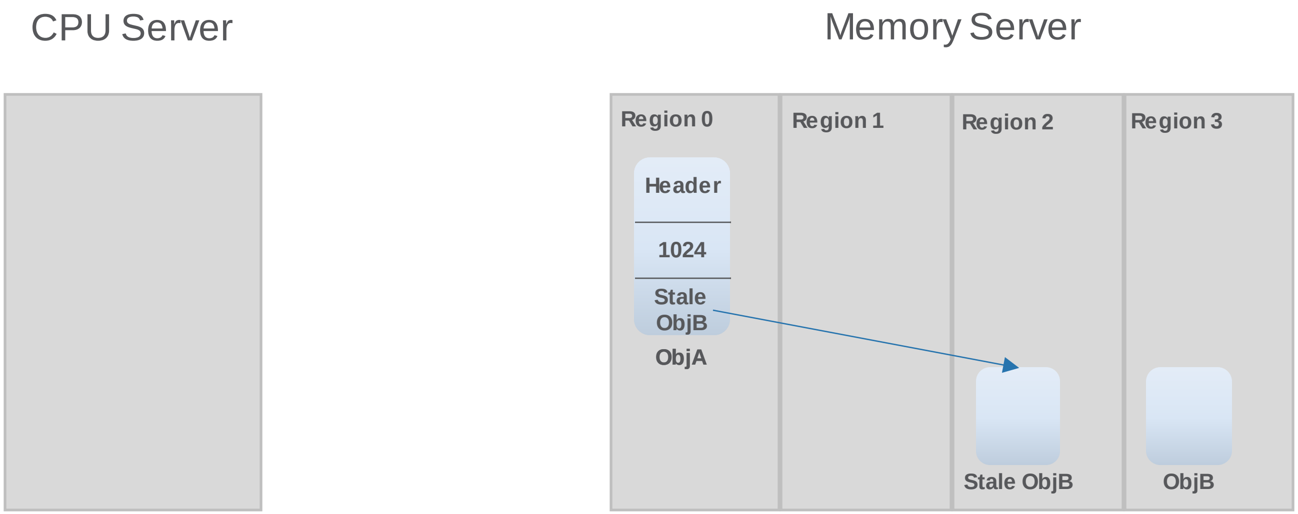
No efficient way to enforce memory coherence between the CPU and memory servers

- Concurrent Updating Reference
  - Problem: Overwritten updated references
- Concurrent Evacuation
  - Problem: Lost forwarding address

Heap Indirection Table



Problem #1: Concurrent Updating References



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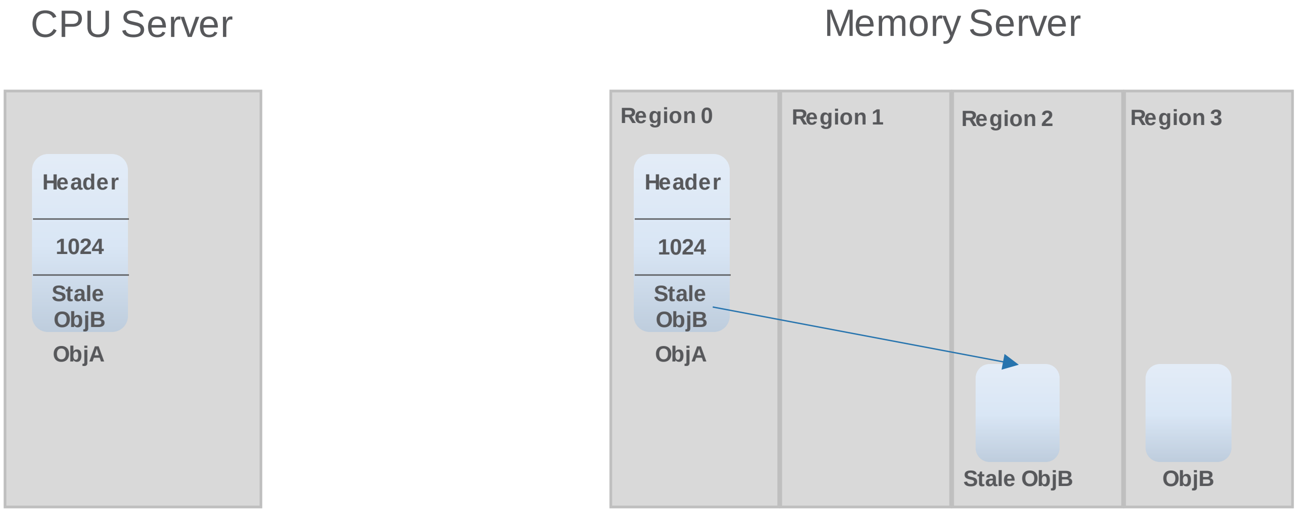

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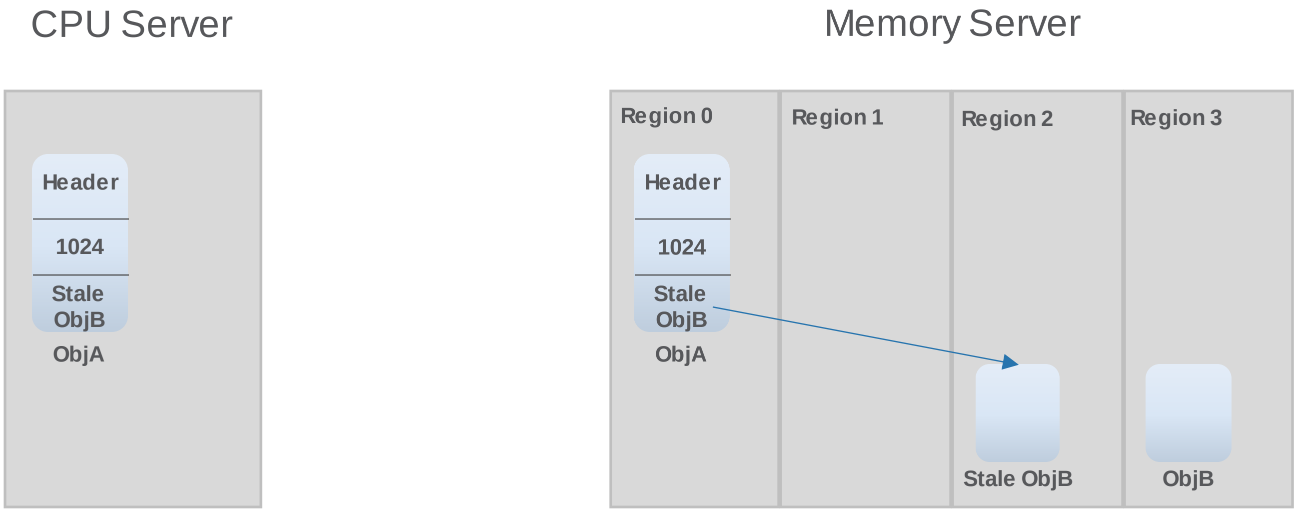

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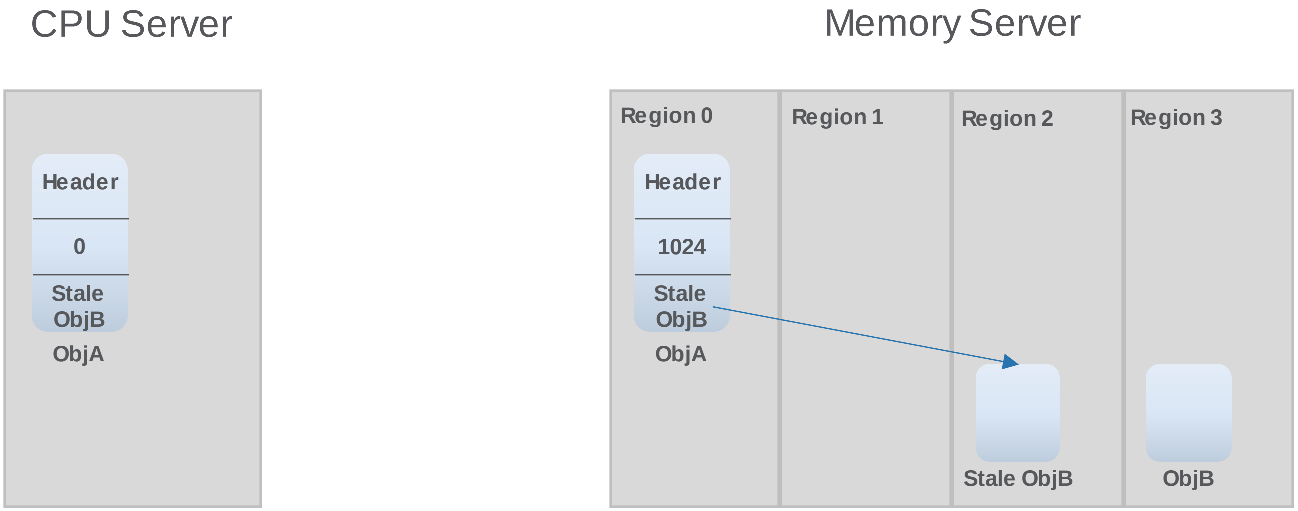

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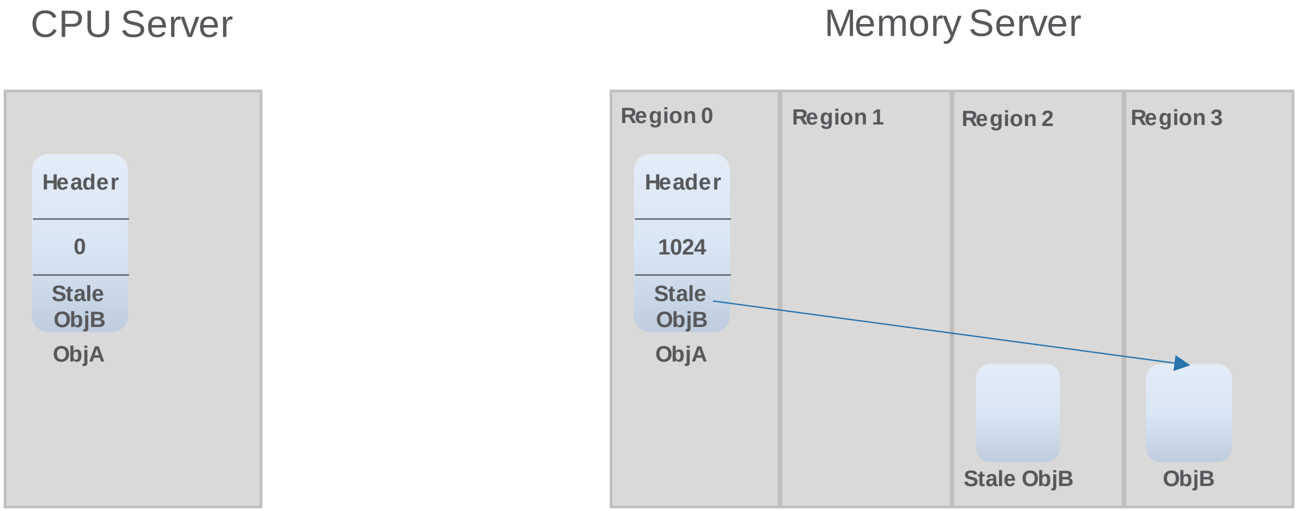

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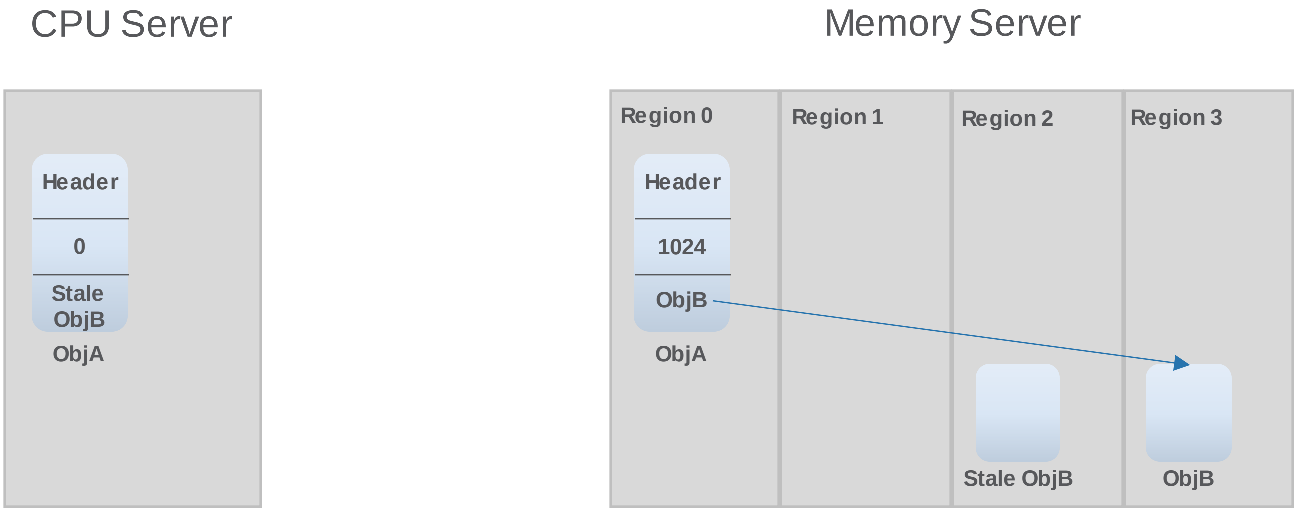

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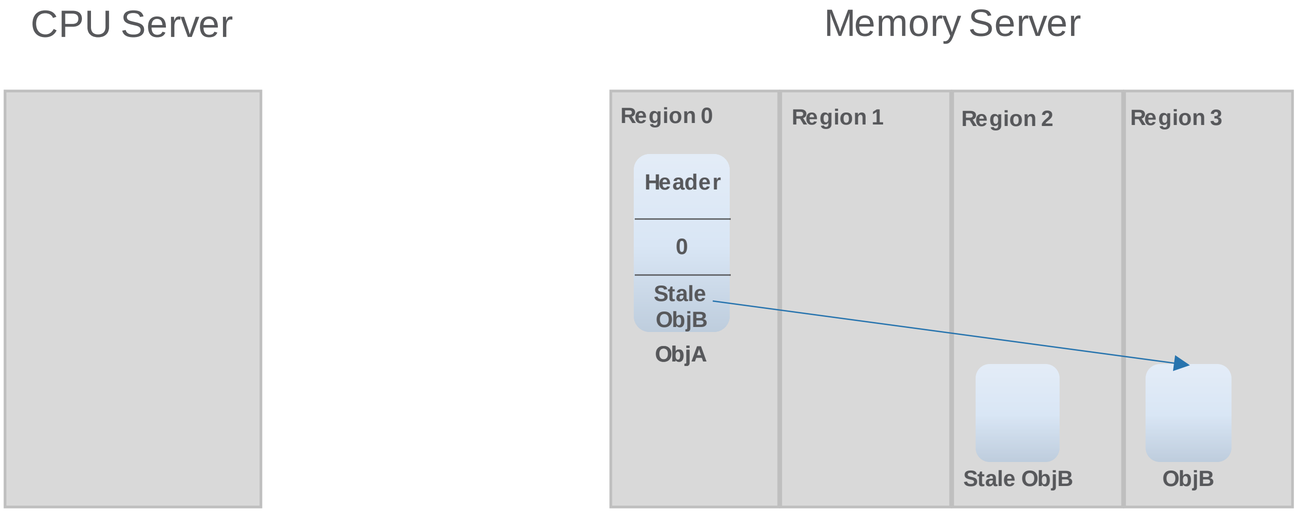

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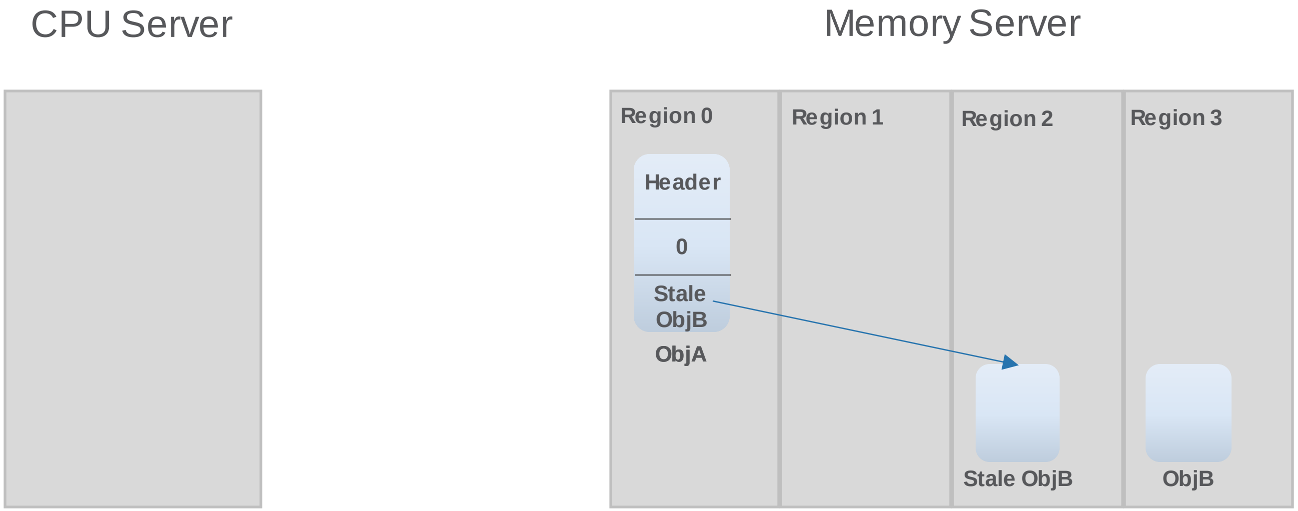

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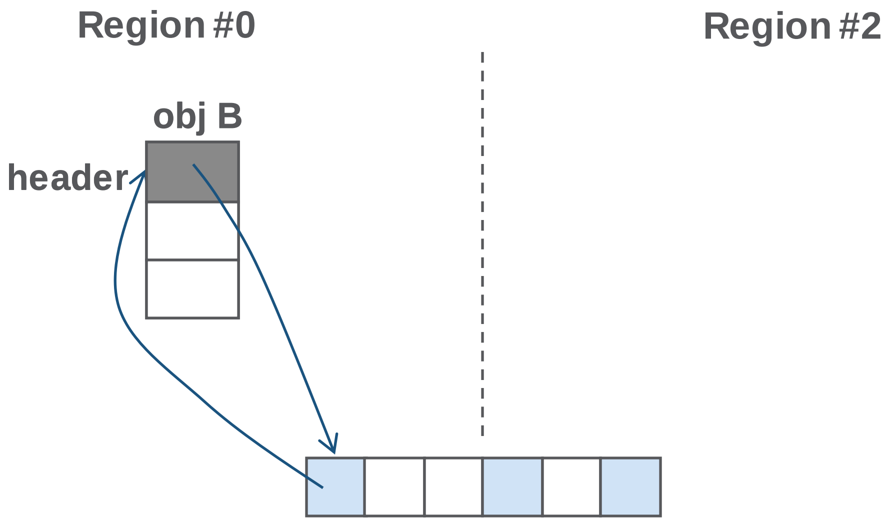
Solution #1

- Eliminate the need to directly update pointers at both the CPU and memory servers



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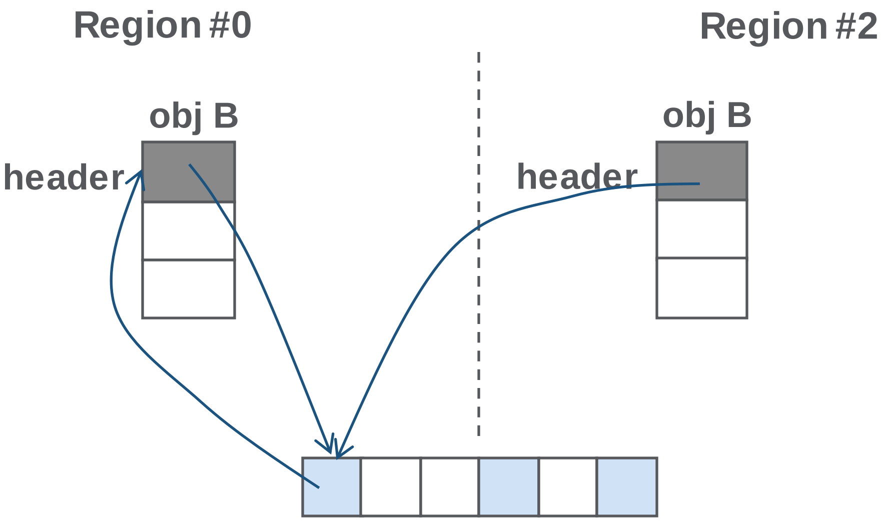

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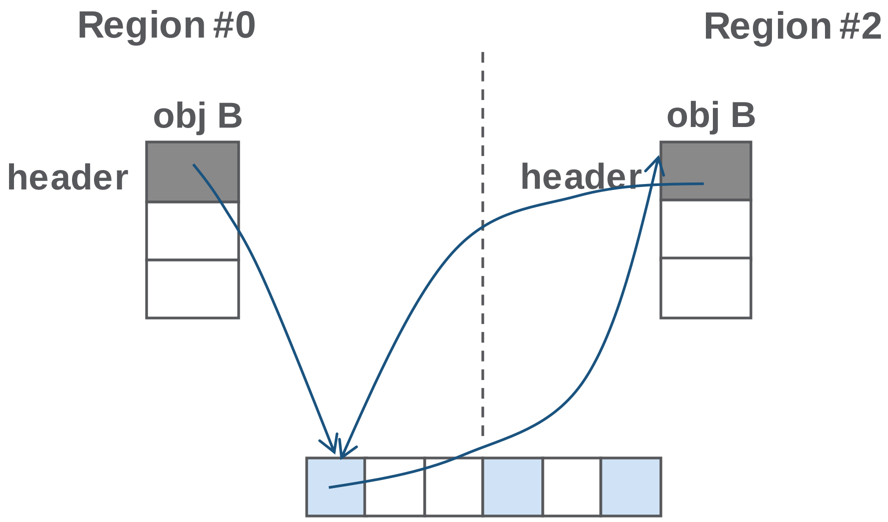
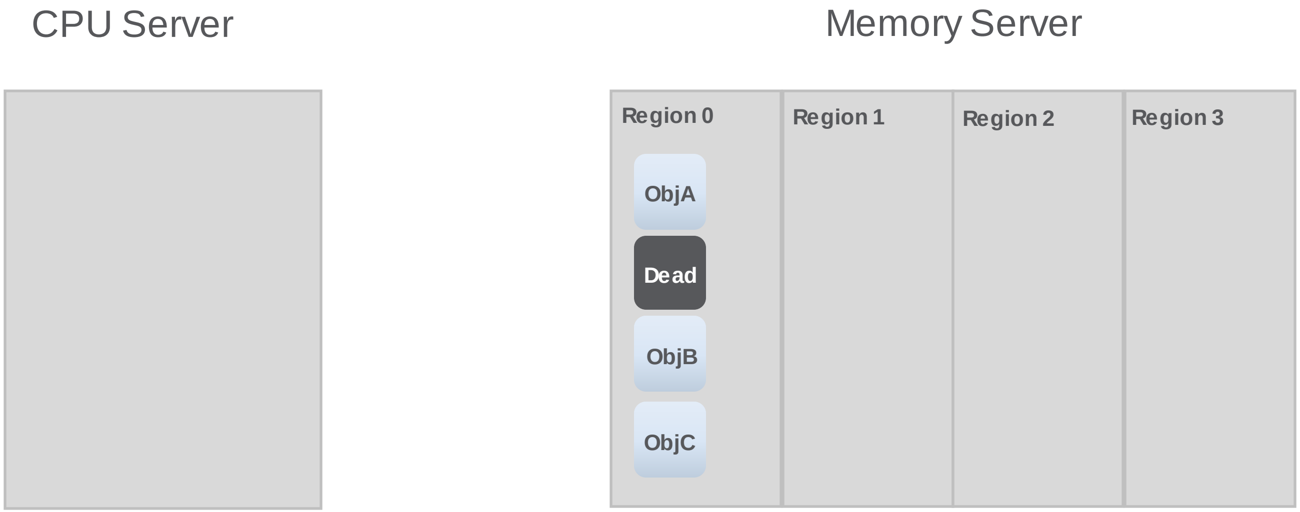


Problem #2: Concurrent Evacuation



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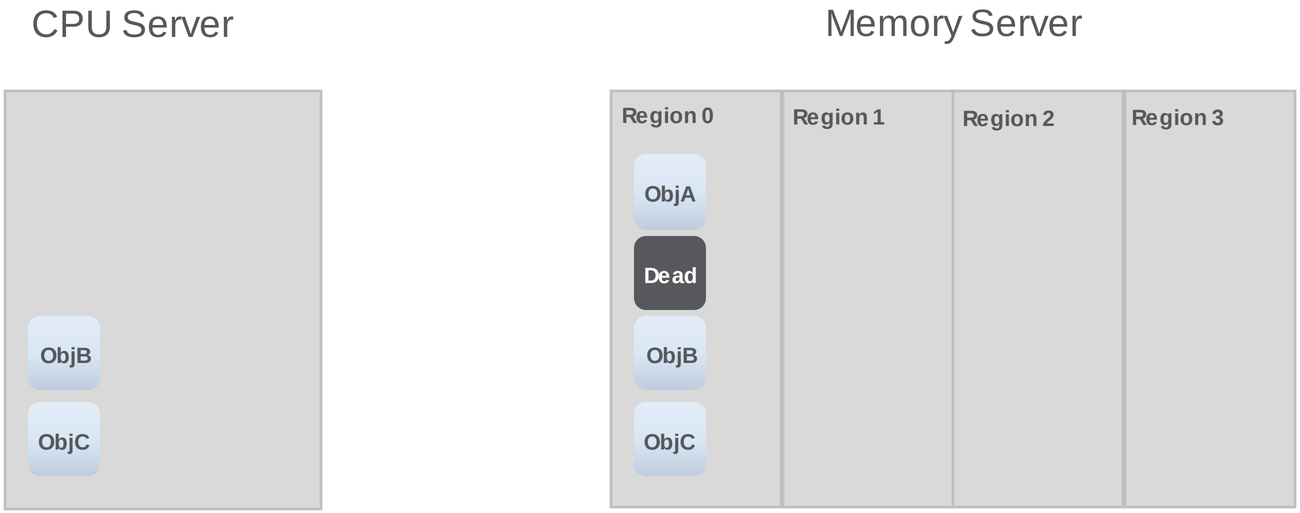

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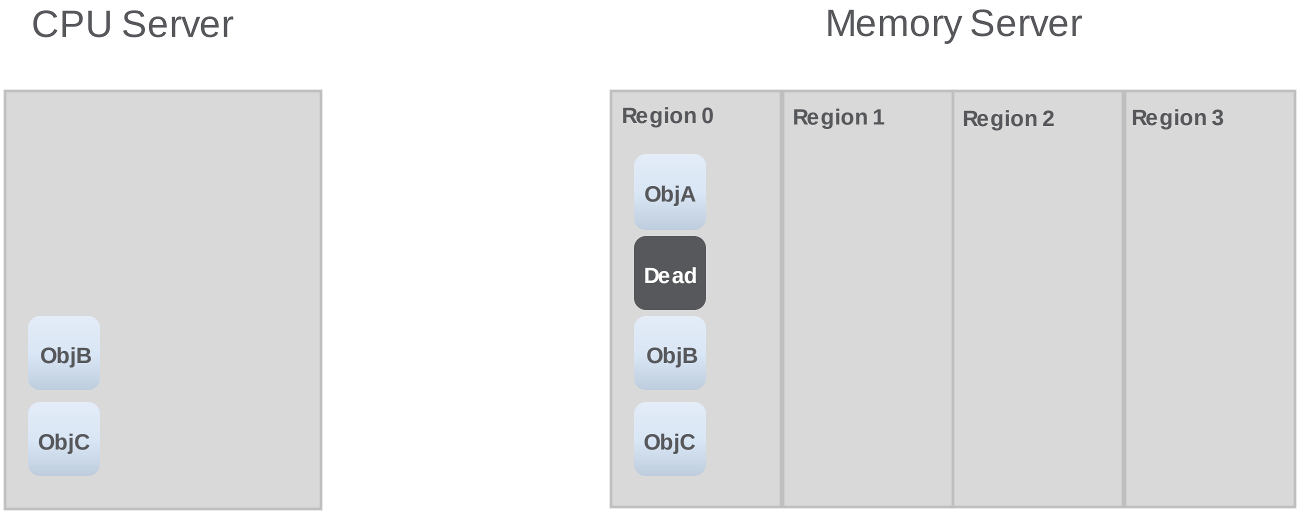

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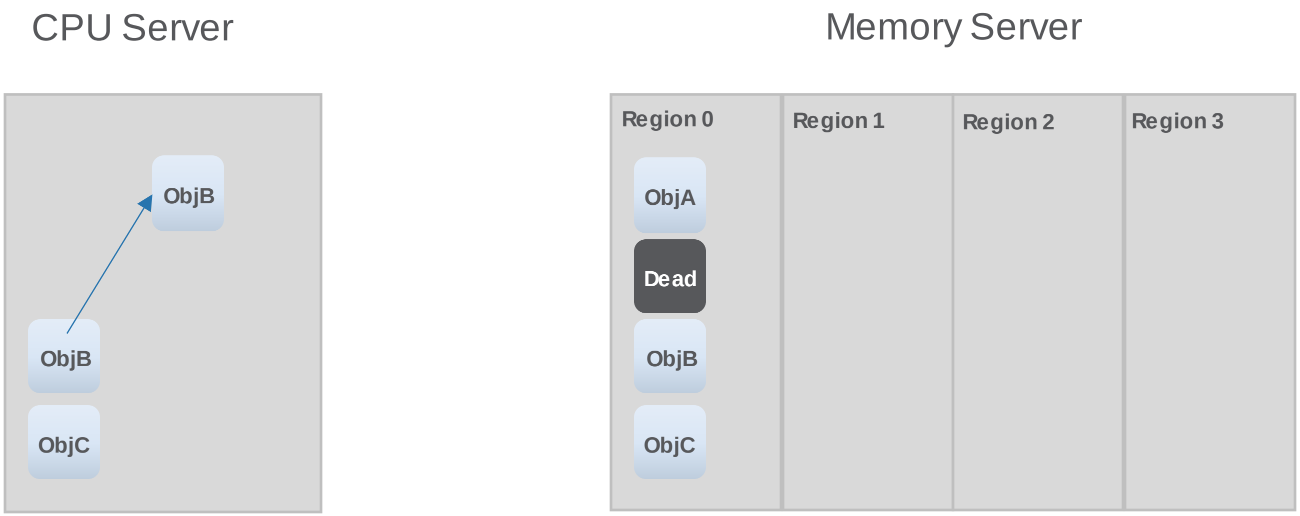

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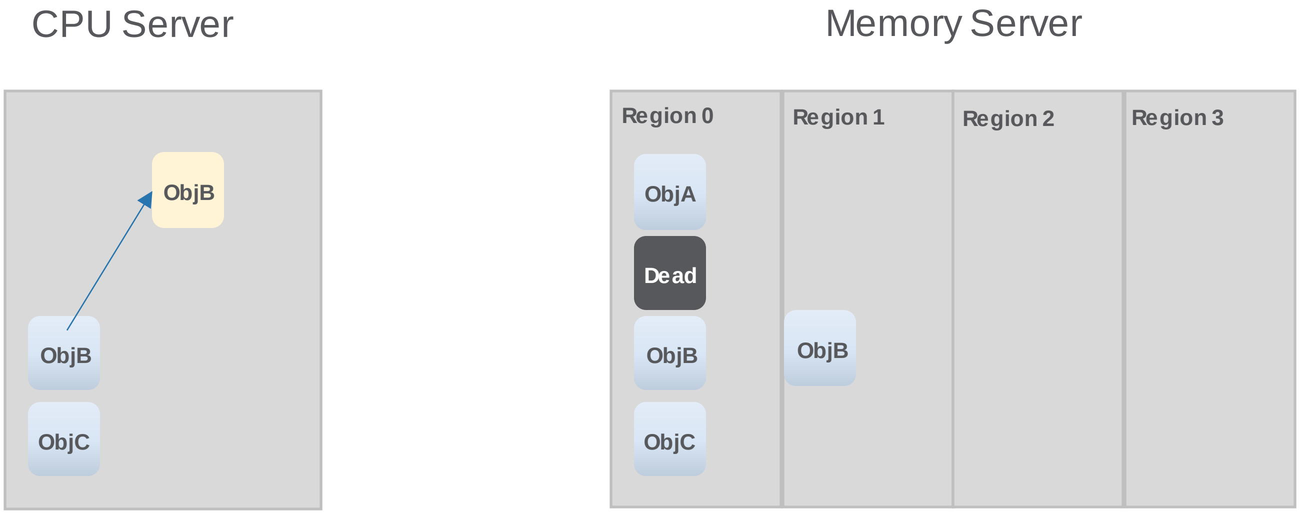

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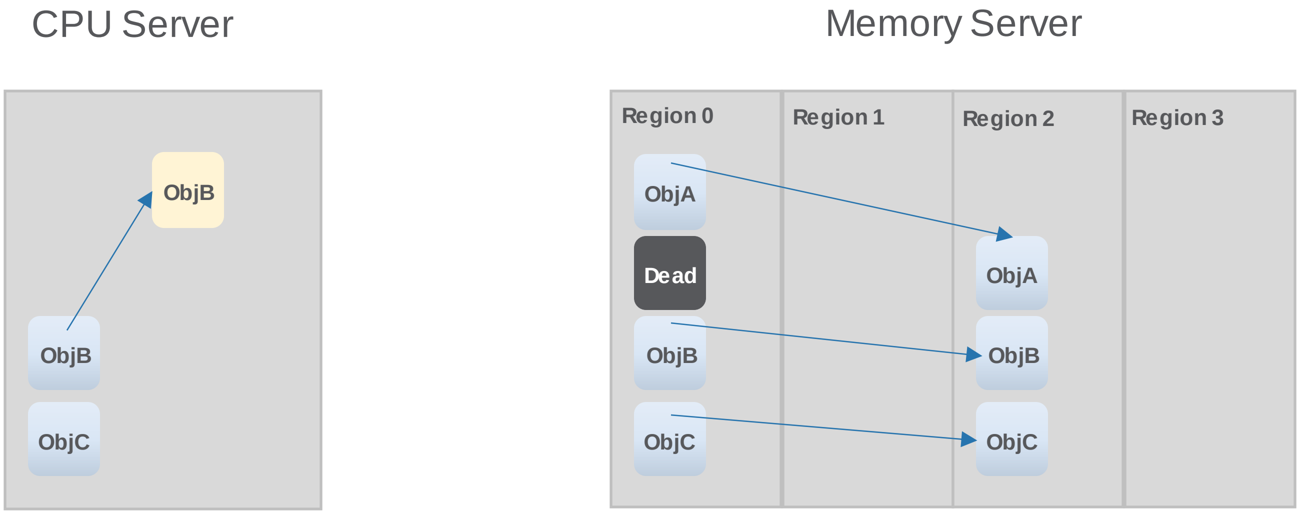

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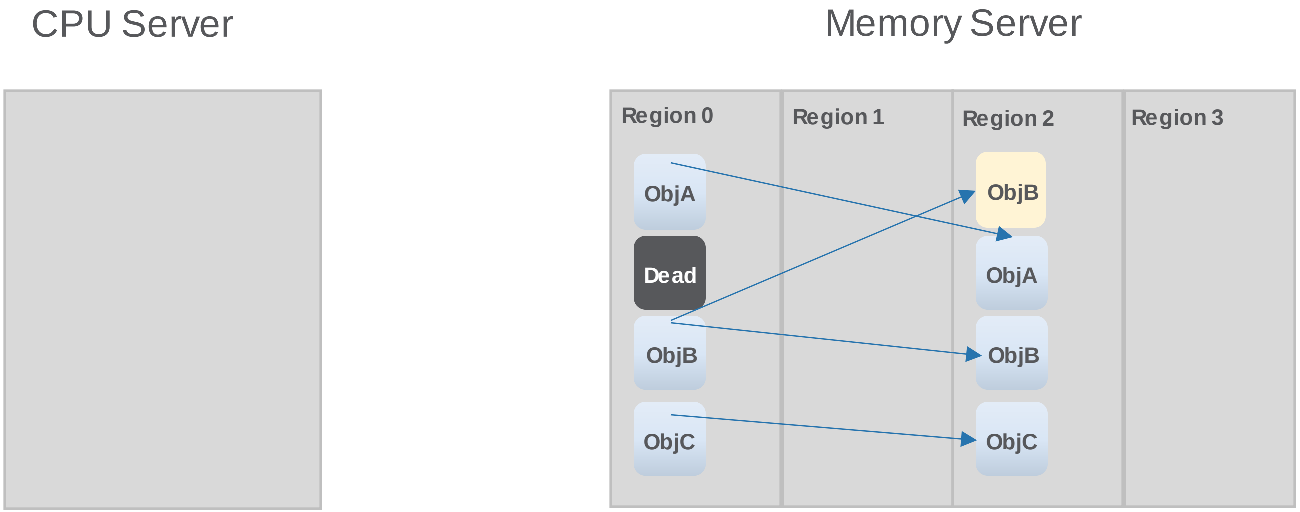

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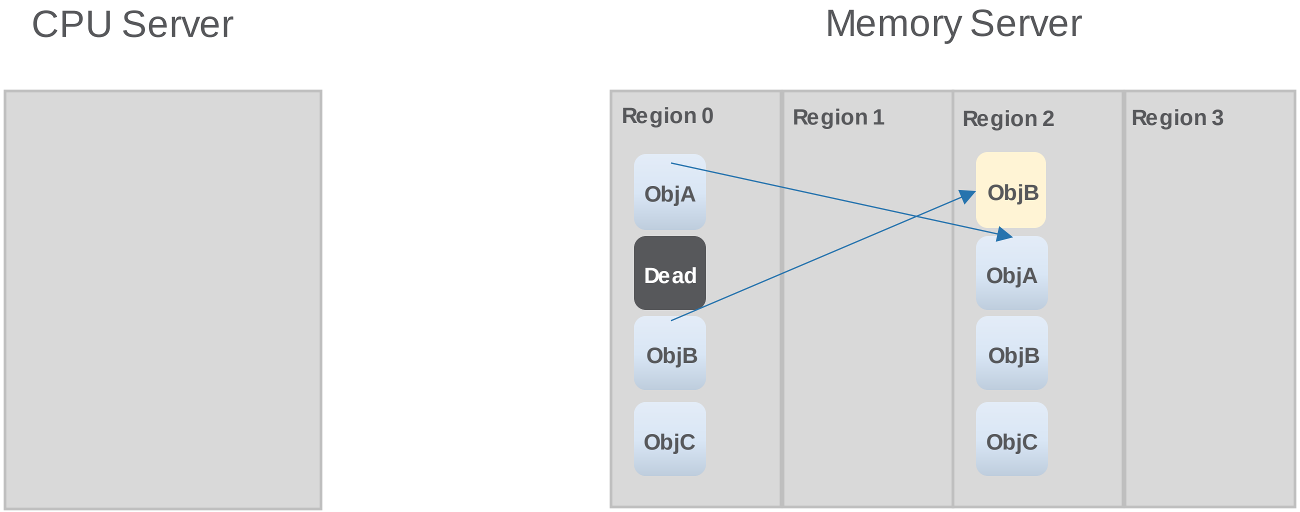

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Solution #2

- Causes of Problem #2:
  - JVM accesses data at object-level, while the OS kernel manages data at page-level.
  - Synchronization on each object access would incur too much overhead

Tablet Lock

↓

Region-level Synchronization

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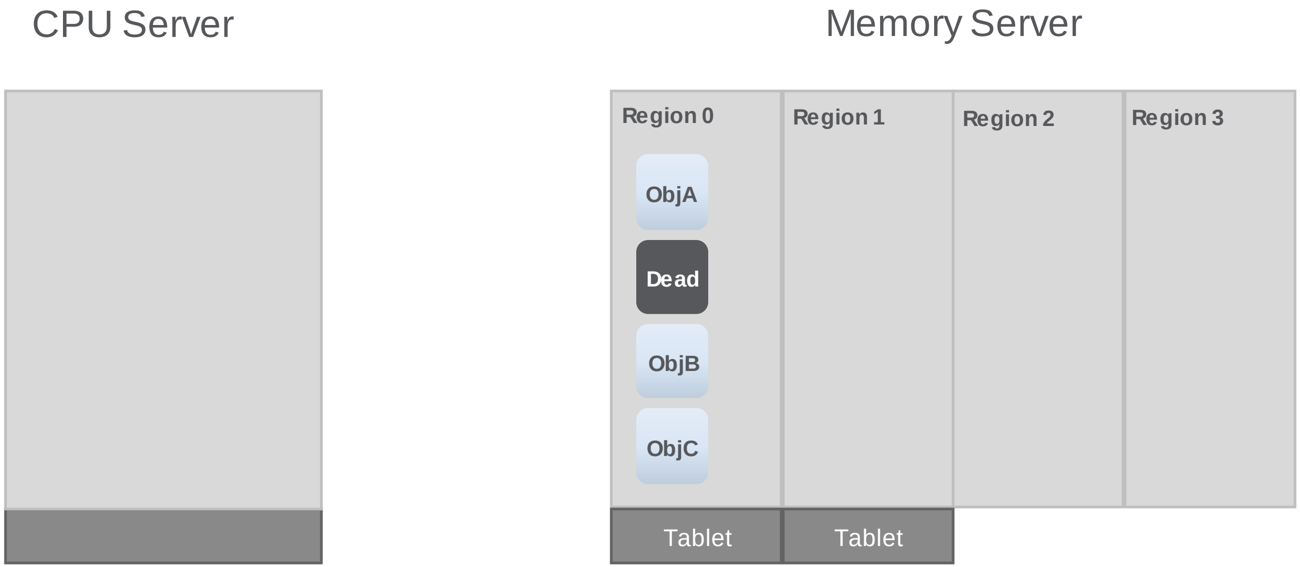
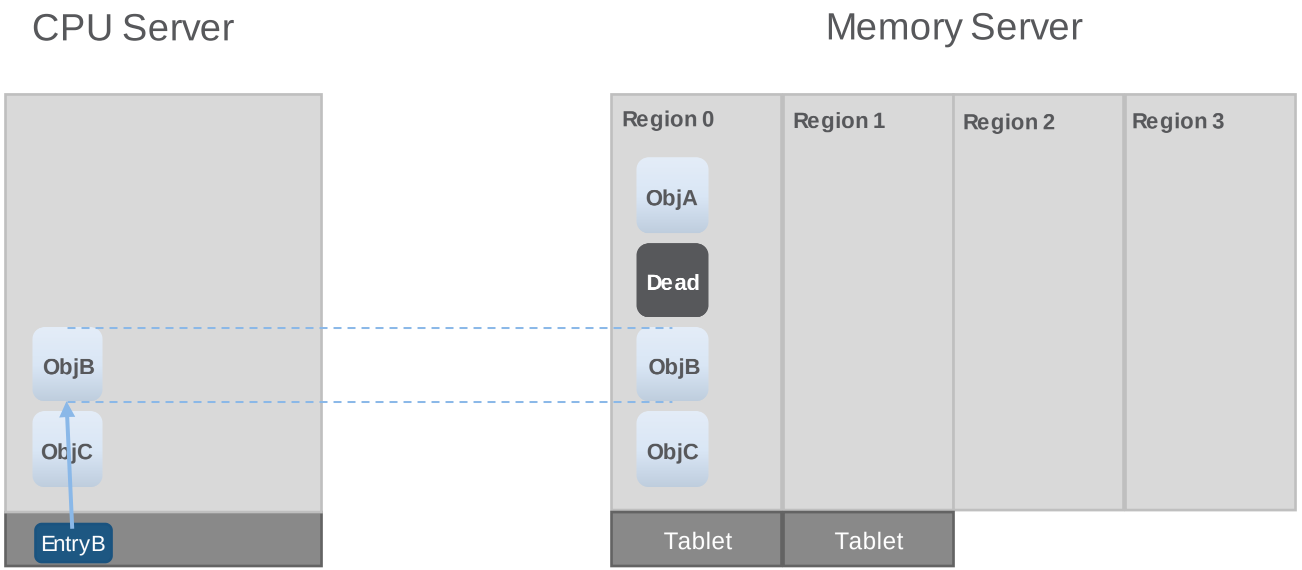
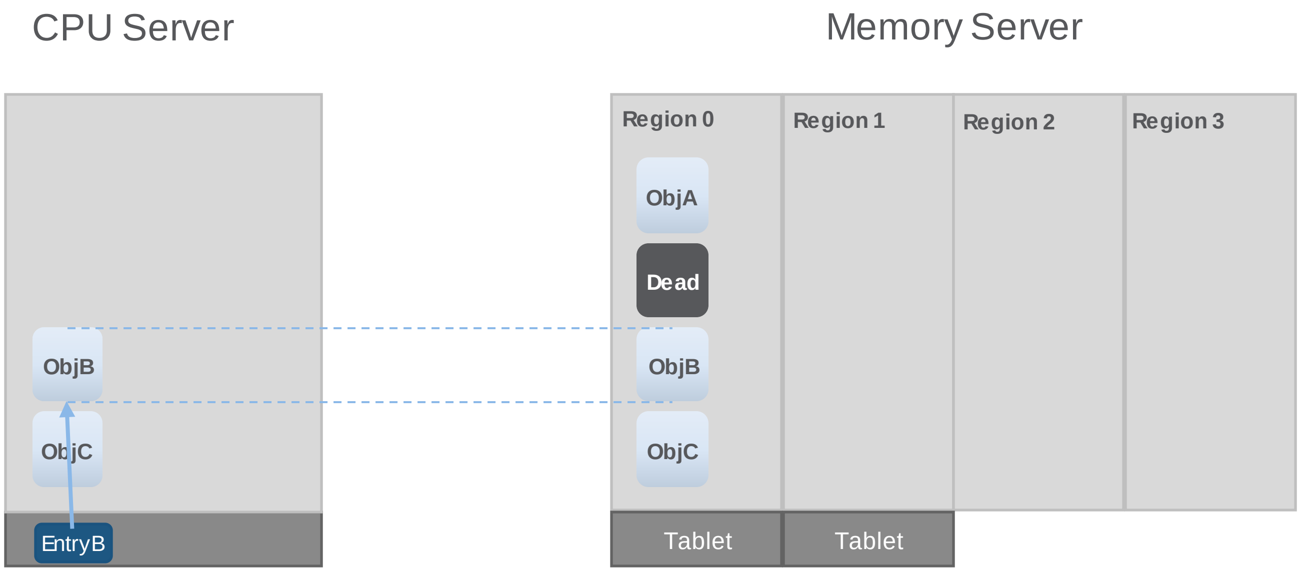
Solution #2


CPU Server
Memory Server
Region 0
Region 1
Region 2
Region 3
ObjA
Dead
ObjB
ObjC
Tablet
Tablet

Solution #2


CPU Server
Memory Server
Region 0
Region 1
Region 2
Region 3
ObjA
Dead
ObjB
ObjC
ObjB
ObjC
EntryB
Tablet
Tablet

Solution #2



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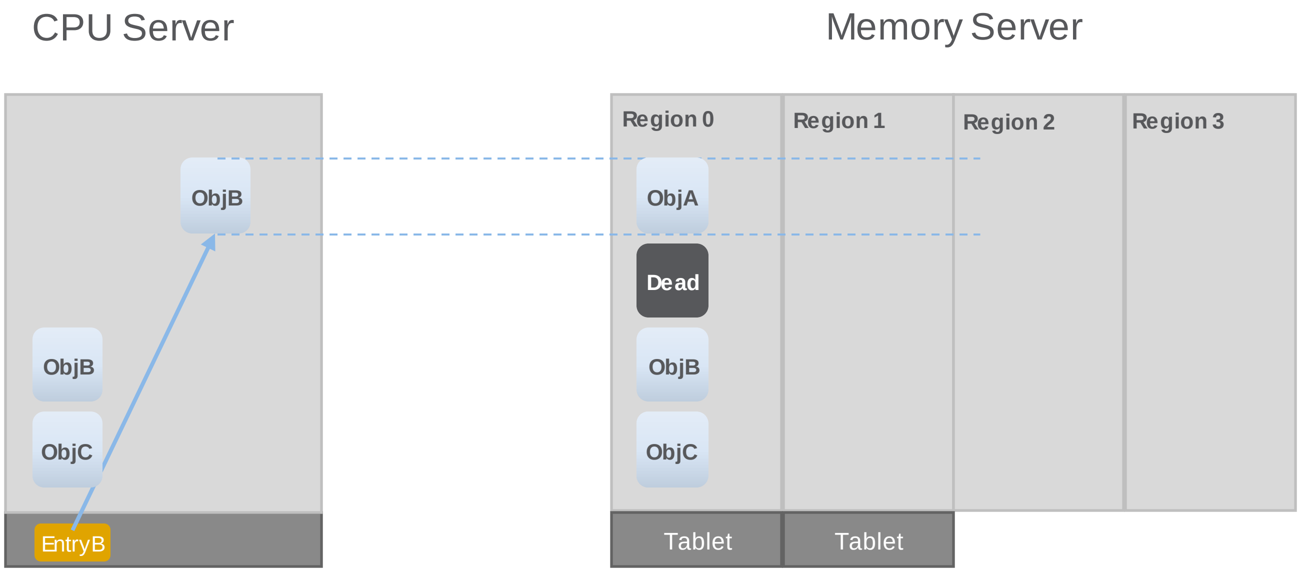
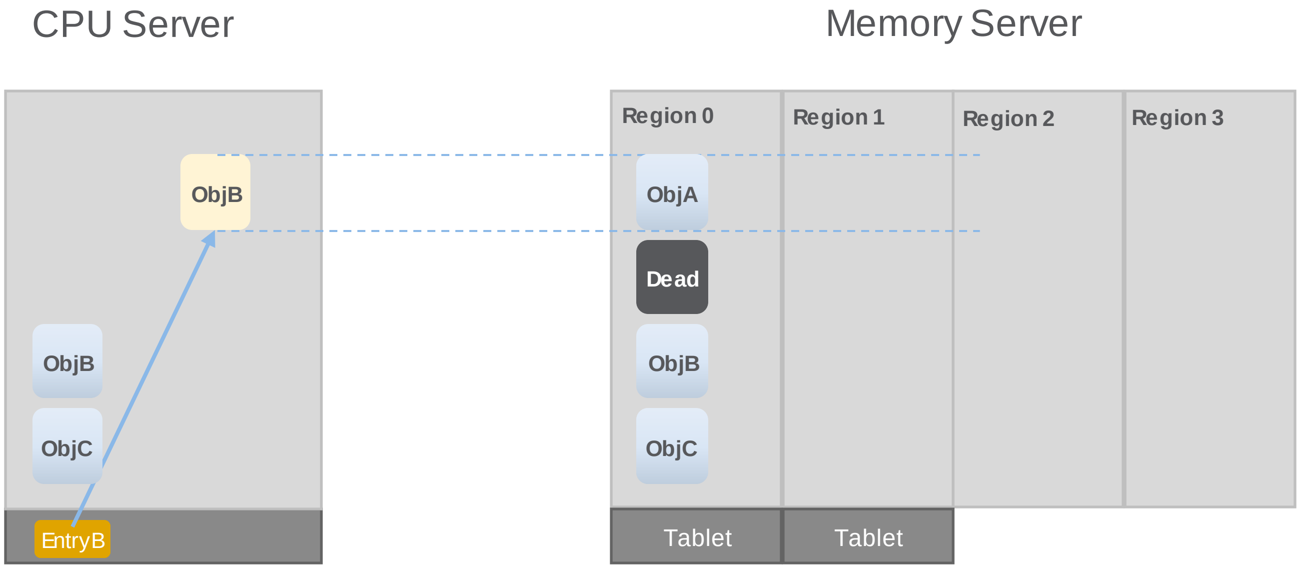


CPU Server
Memory Server
ObjB
ObjB
ObjC
EntryB
Region 0
Region 1
Region 2
Region 3
ObjA
Dead
ObjB
ObjC
Tablet
Tablet

Solution #2



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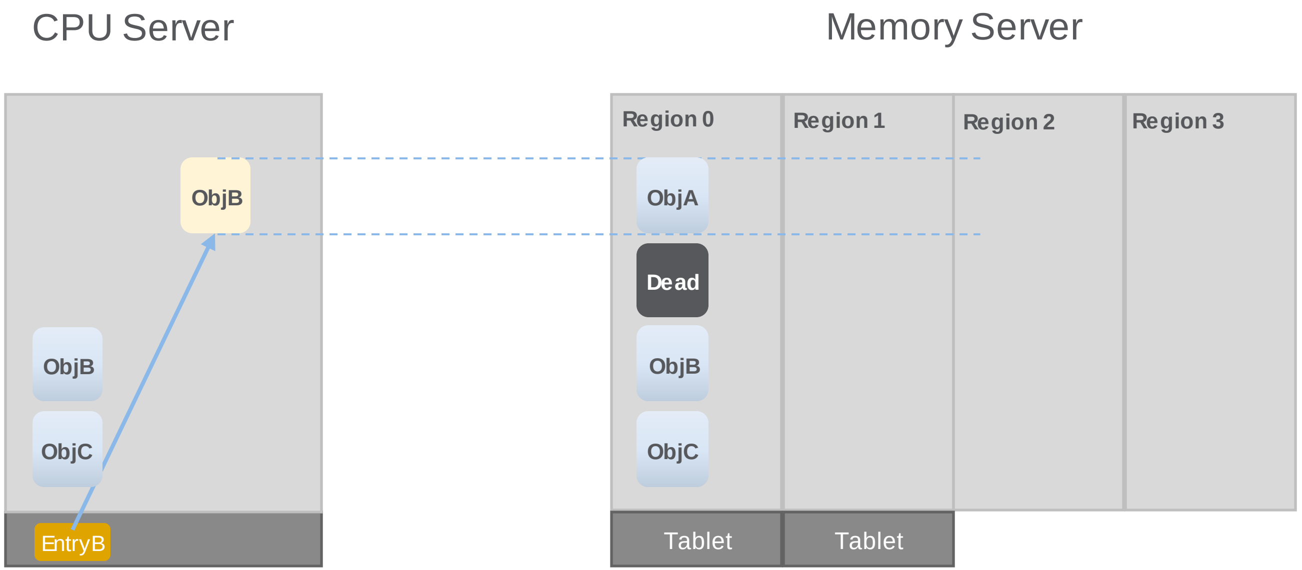
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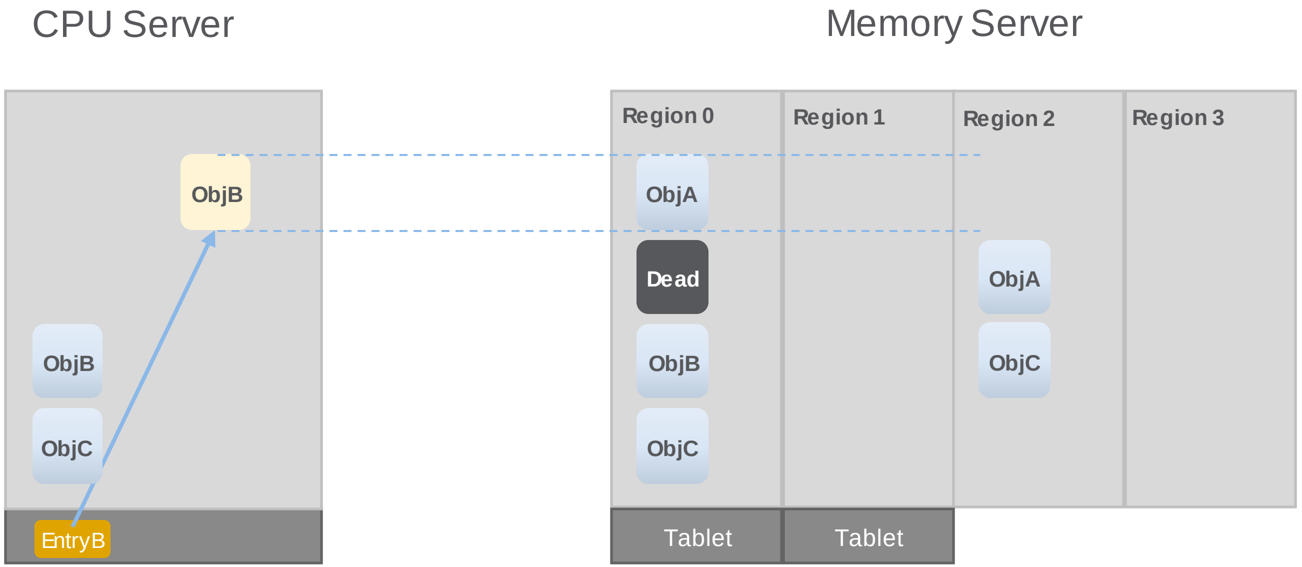

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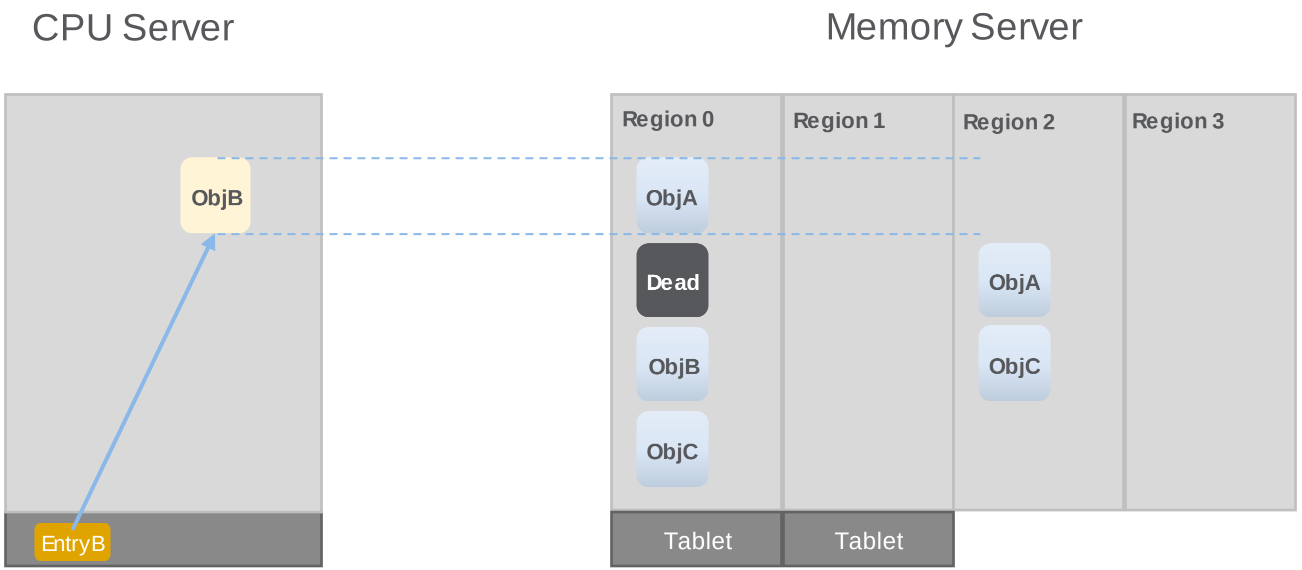

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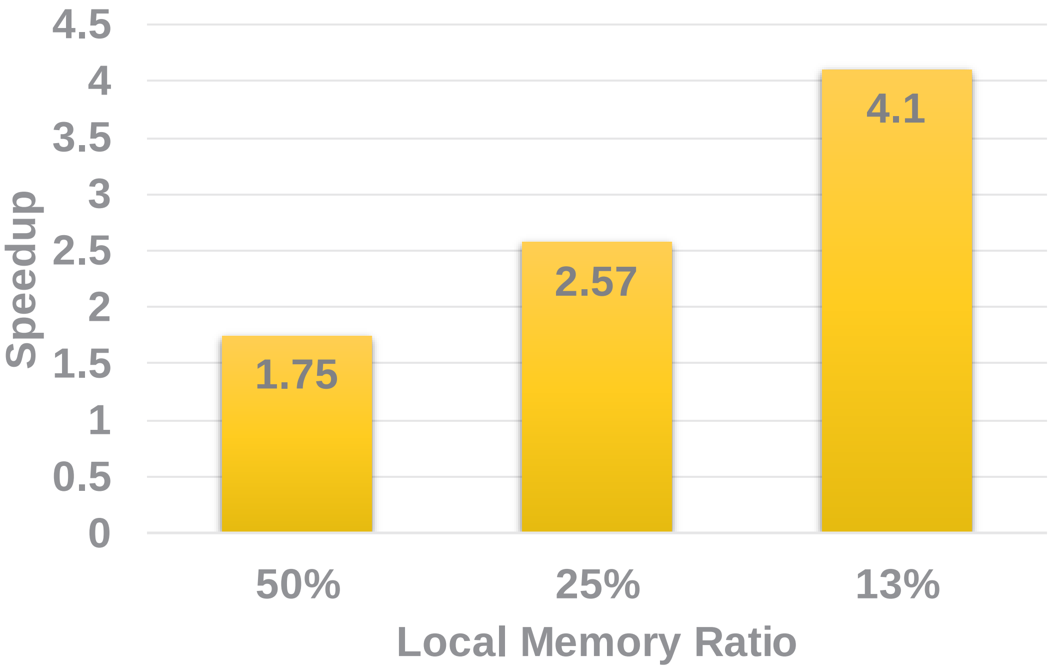
Benchmarks

- We evaluate Mako on 7 workloads under three different local memory ratios: 50%, 25%, and 13%
  - Dacapo: Tradesoap, Tradebeans, H2
  - Apache Cassandra: Insert Intensive, Update Intensive
  - Apache Spark: PageRank, Transitive Closure

- We compare Mako with
  - Shenandoah: a modern concurrent collector in OpenJDK
  - Semeru: a G1-based generational GC for disaggregated memory

Results: Throughput



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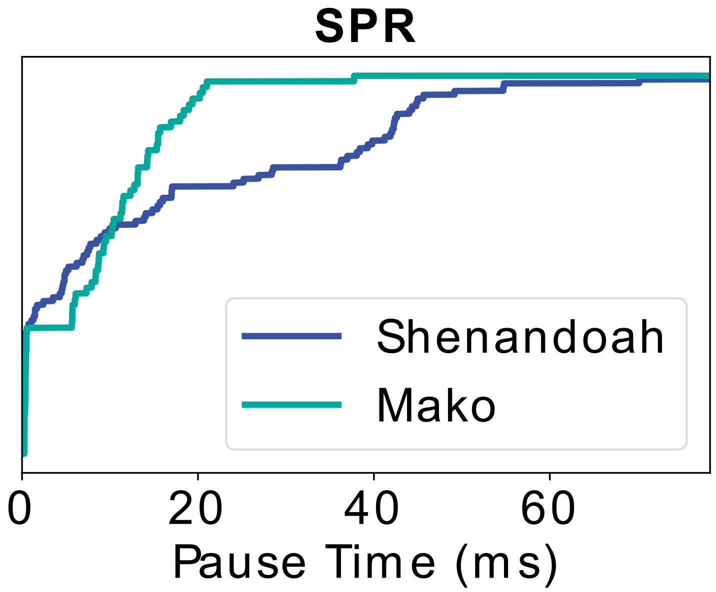
Results: Pause Time

- Mako achieves ~12ms at the 90th-percentile pause time
- Semeru’s pauses are 2 to 3 orders of magnitude longer



Key Takeaways

- Under new hardware and system settings, it might be a good idea to bring back some old concepts and techniques. E.g. Heap Indirection Table

- Offloading GC to memory servers makes compute near data, which improves applications’ throughput

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Q&A