SoCC' 24

PCLive: Pipelined Restoration of Application Containers for Reduced Service Downtime

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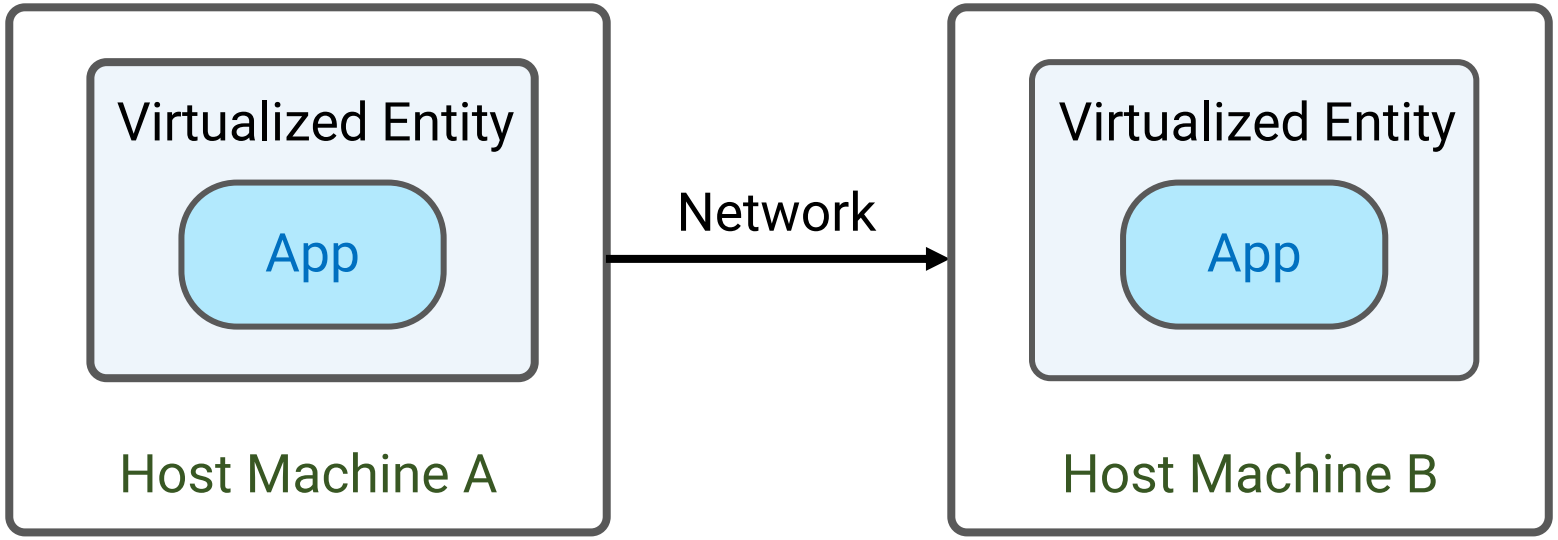
Live Migration



- Usage: Load balancing, system maintenance etc.

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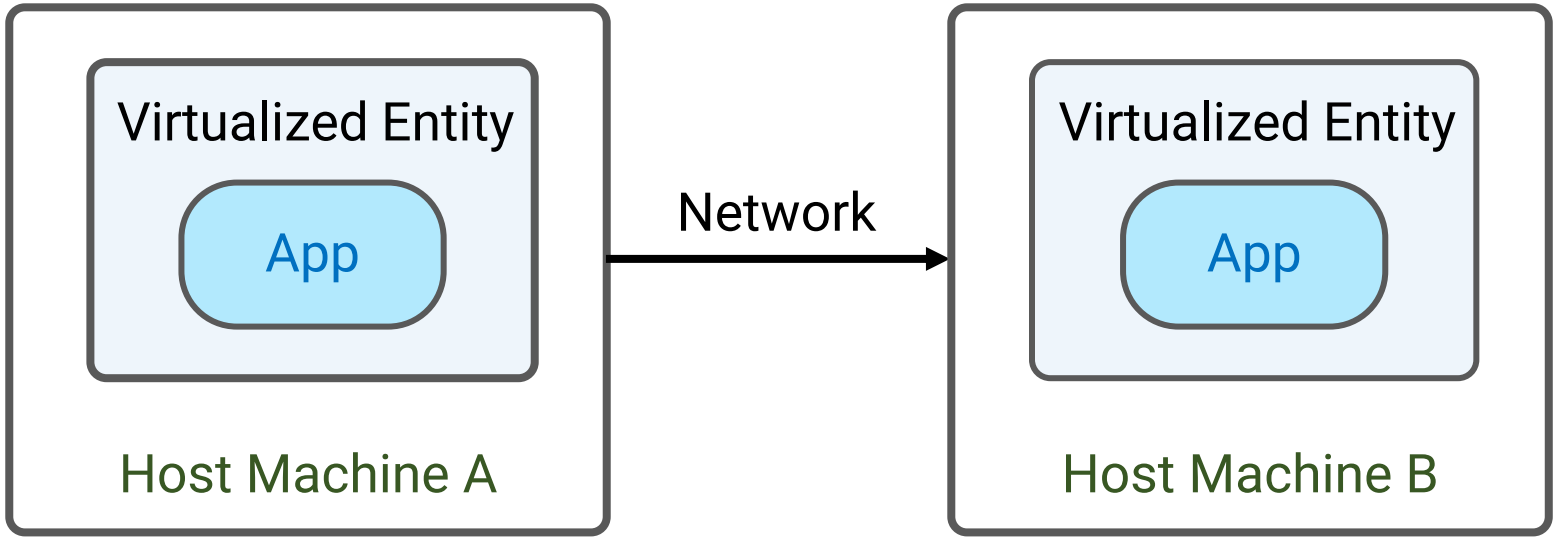

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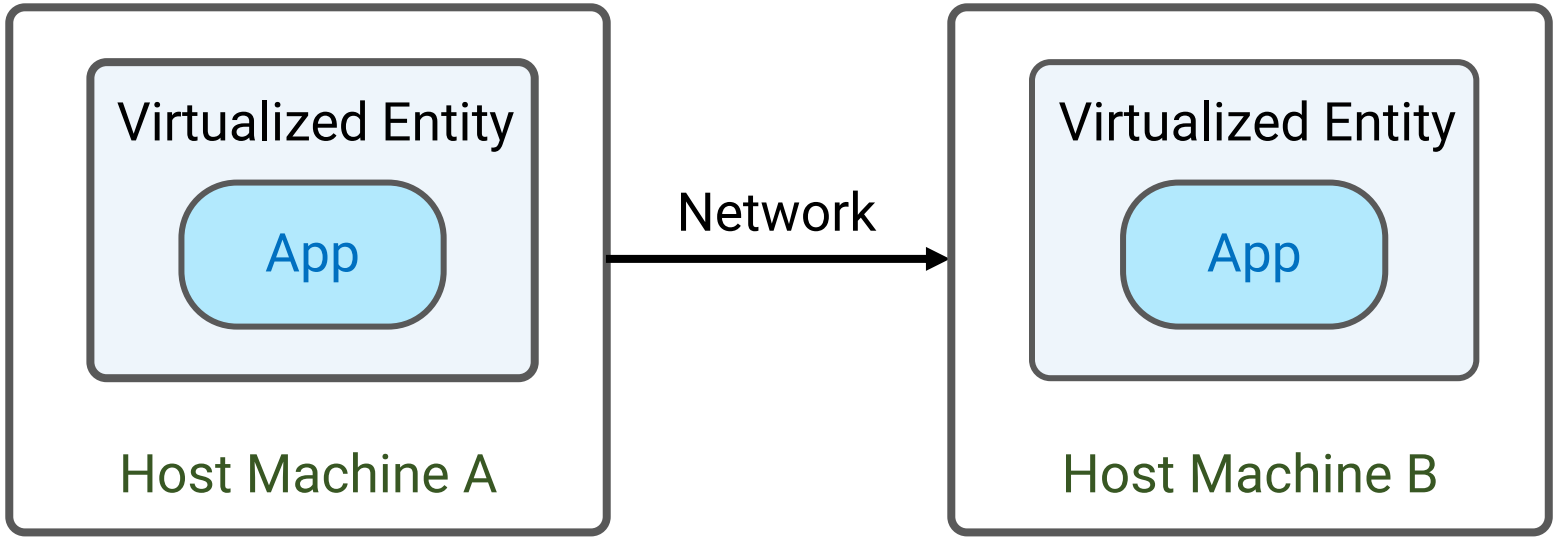

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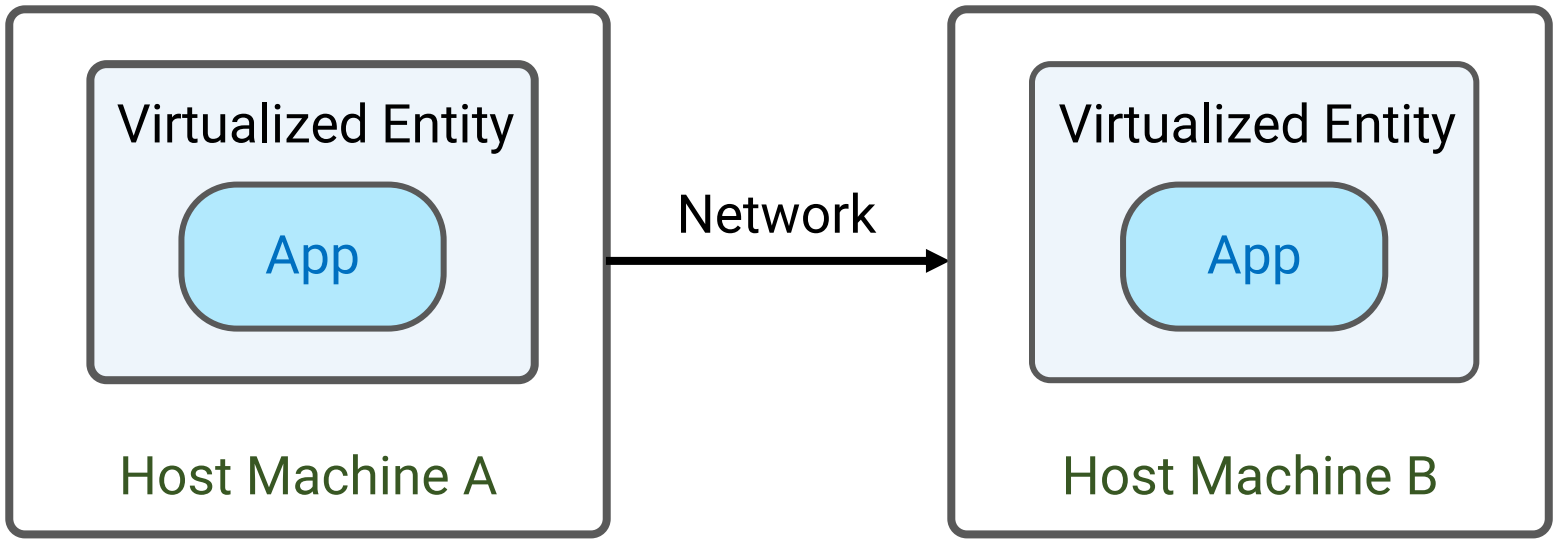

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Paper Scope: To optimize downtime for iterative live migration of containers

Container Migration vs VM Migration: Diskless

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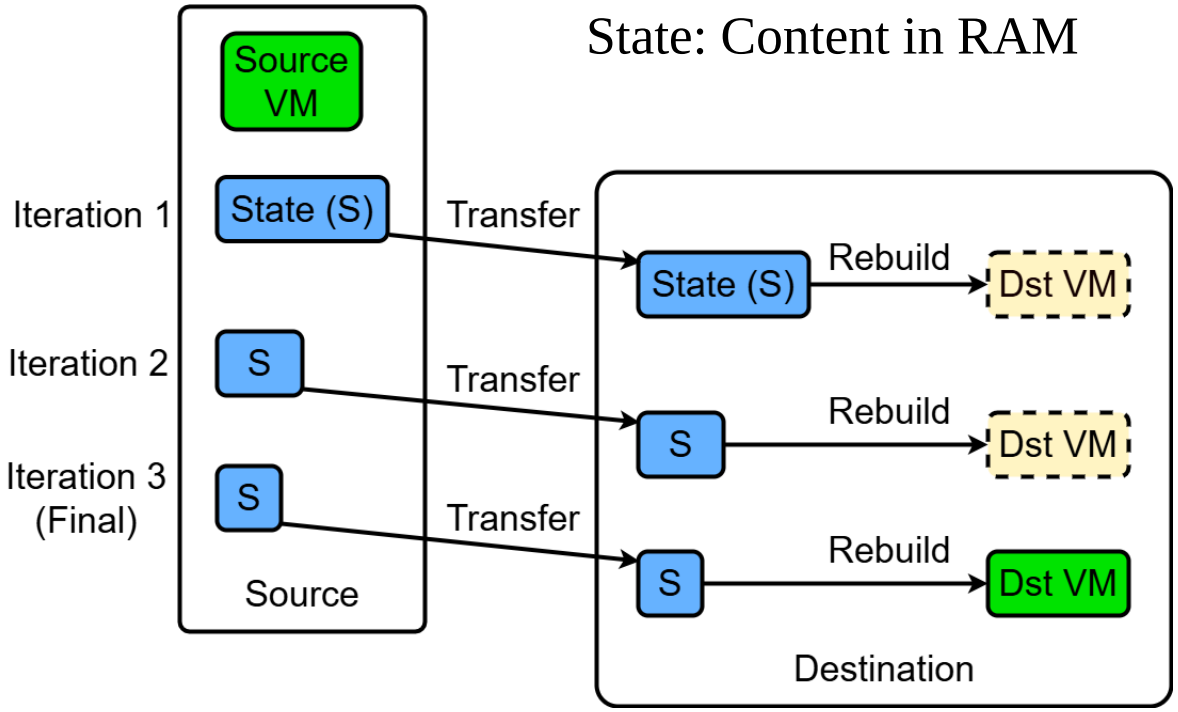

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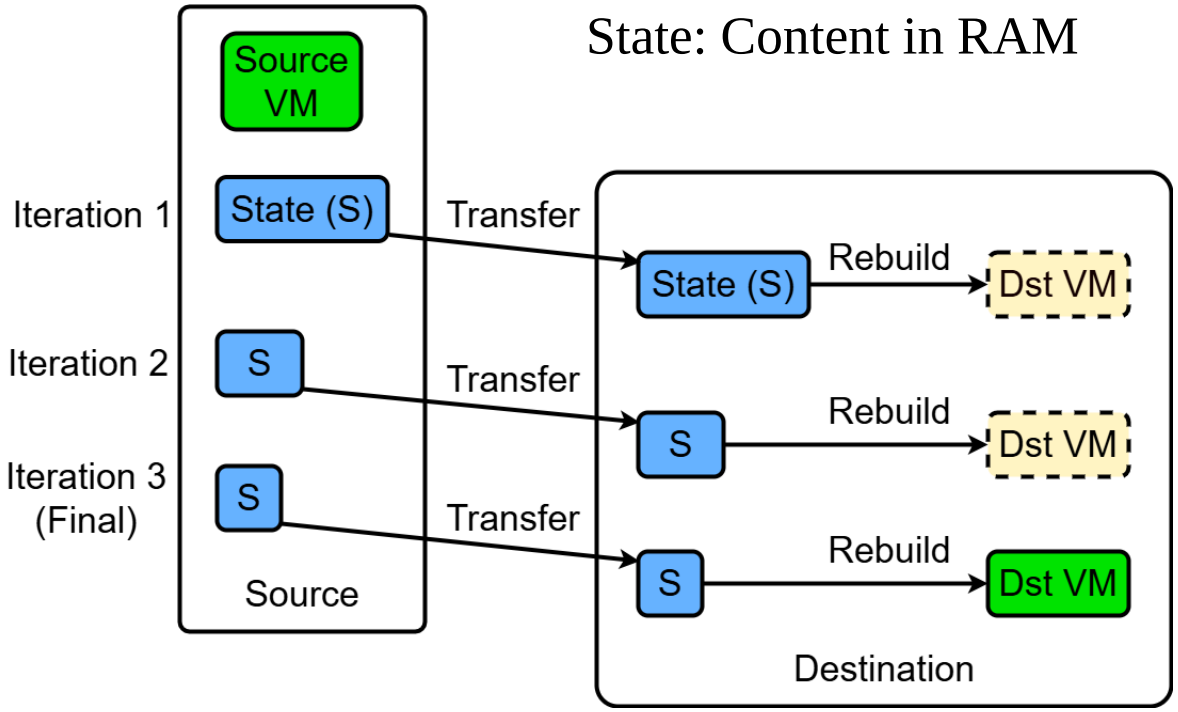

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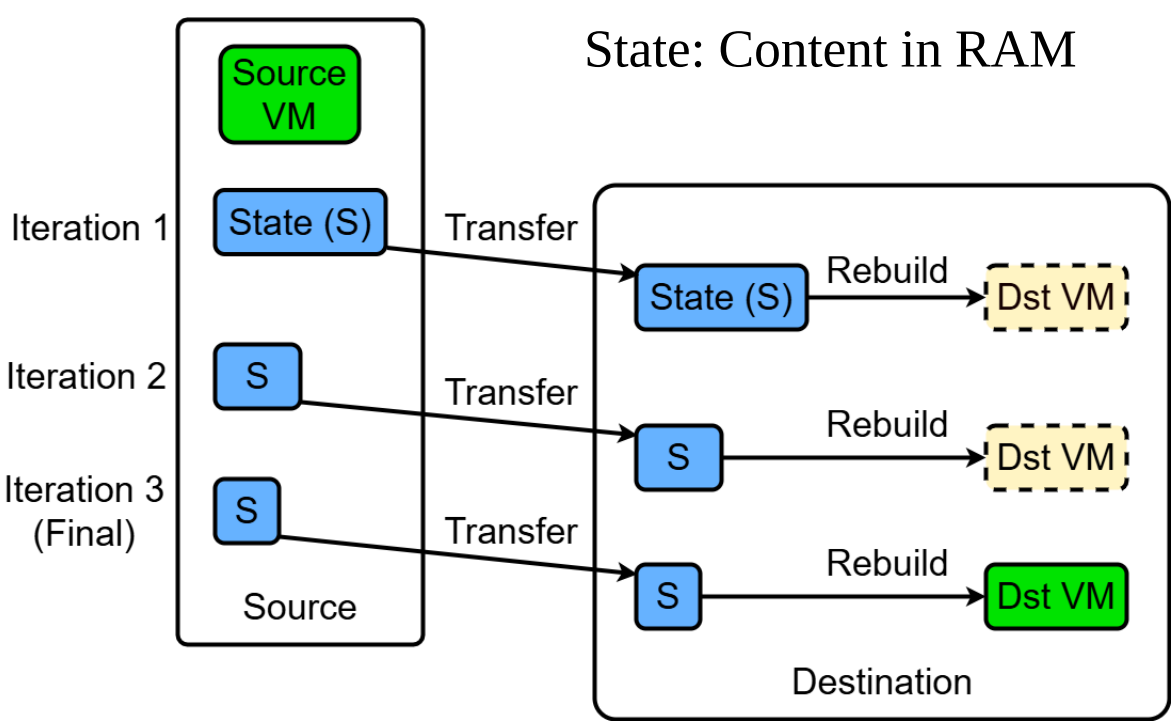

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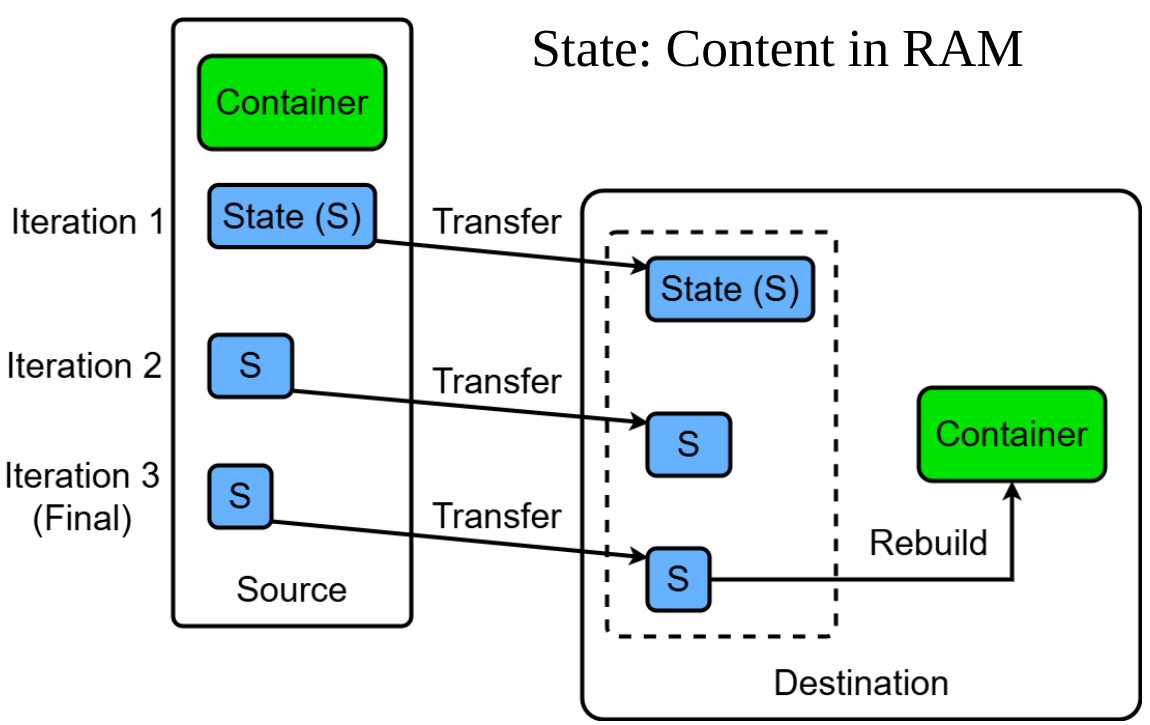

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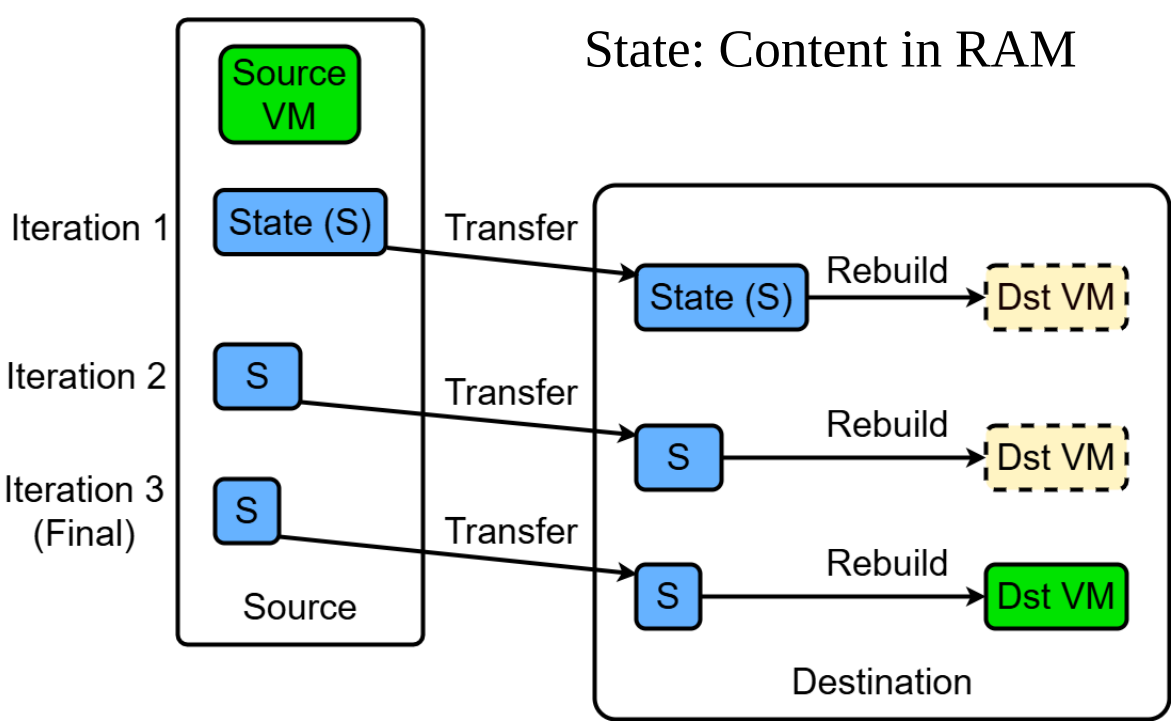

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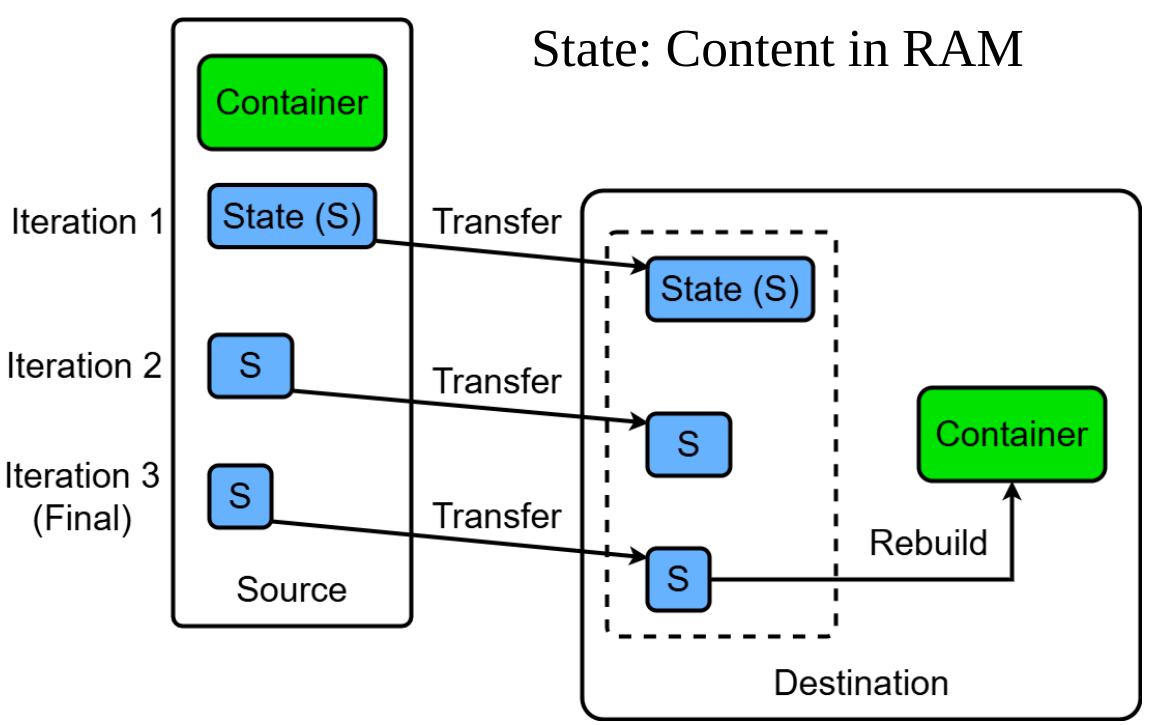

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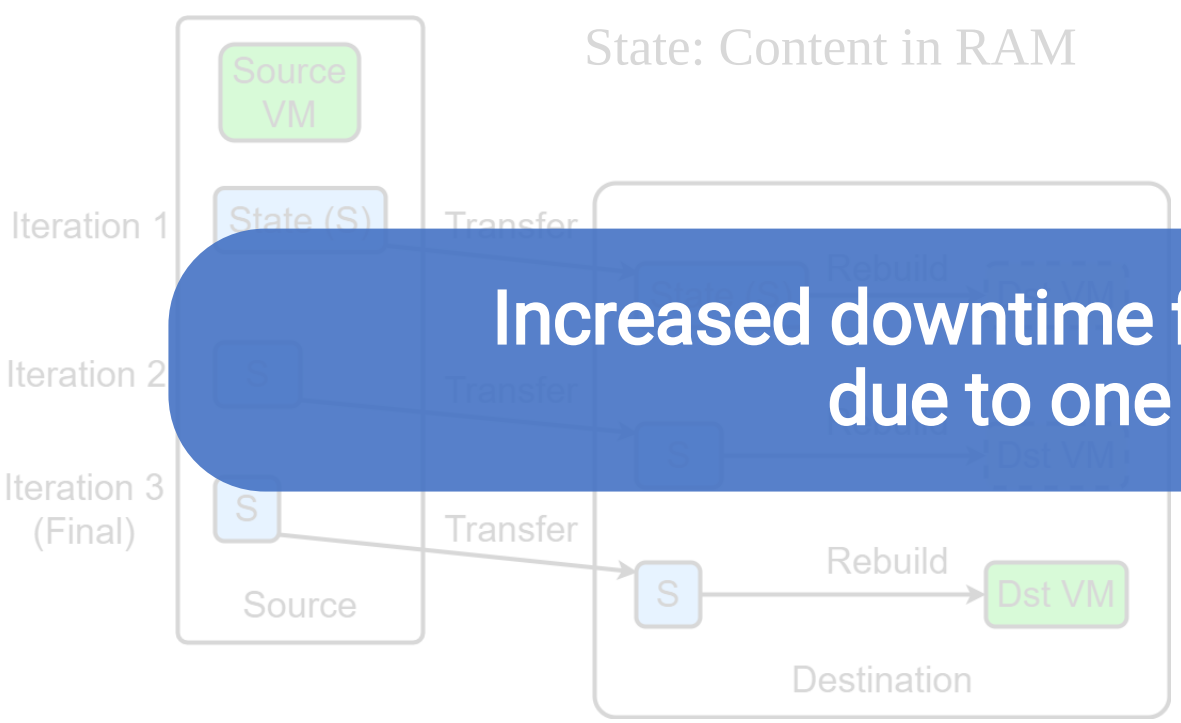

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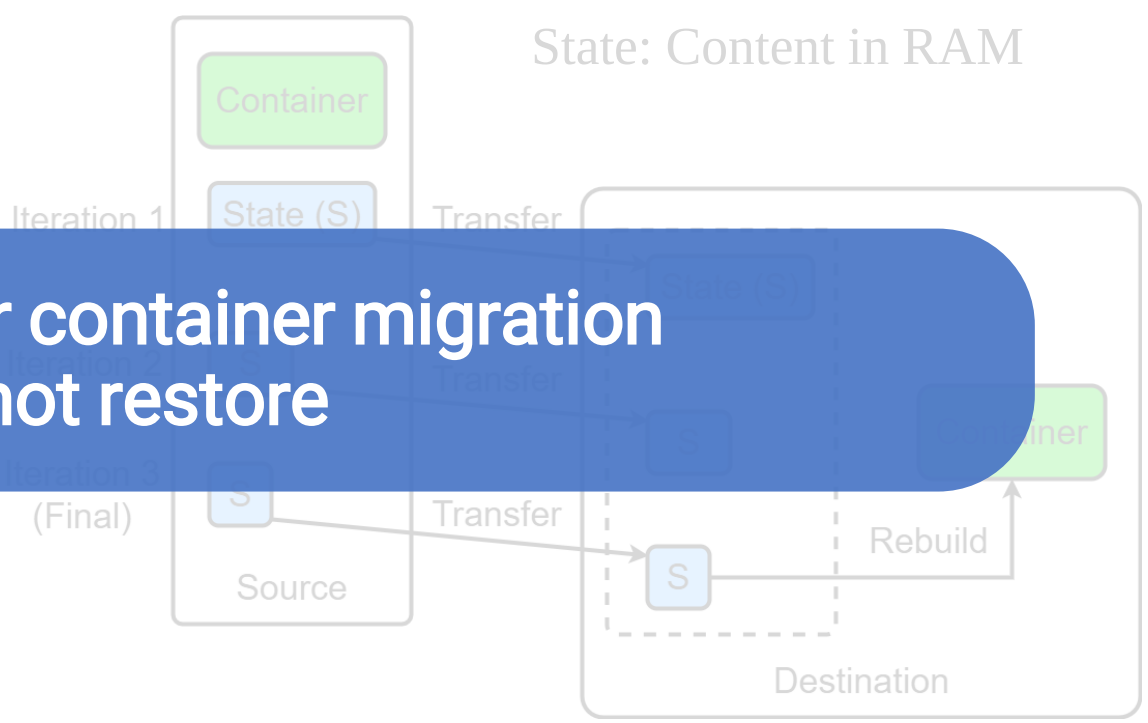

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Increased downtime for container migration due to one shot restore

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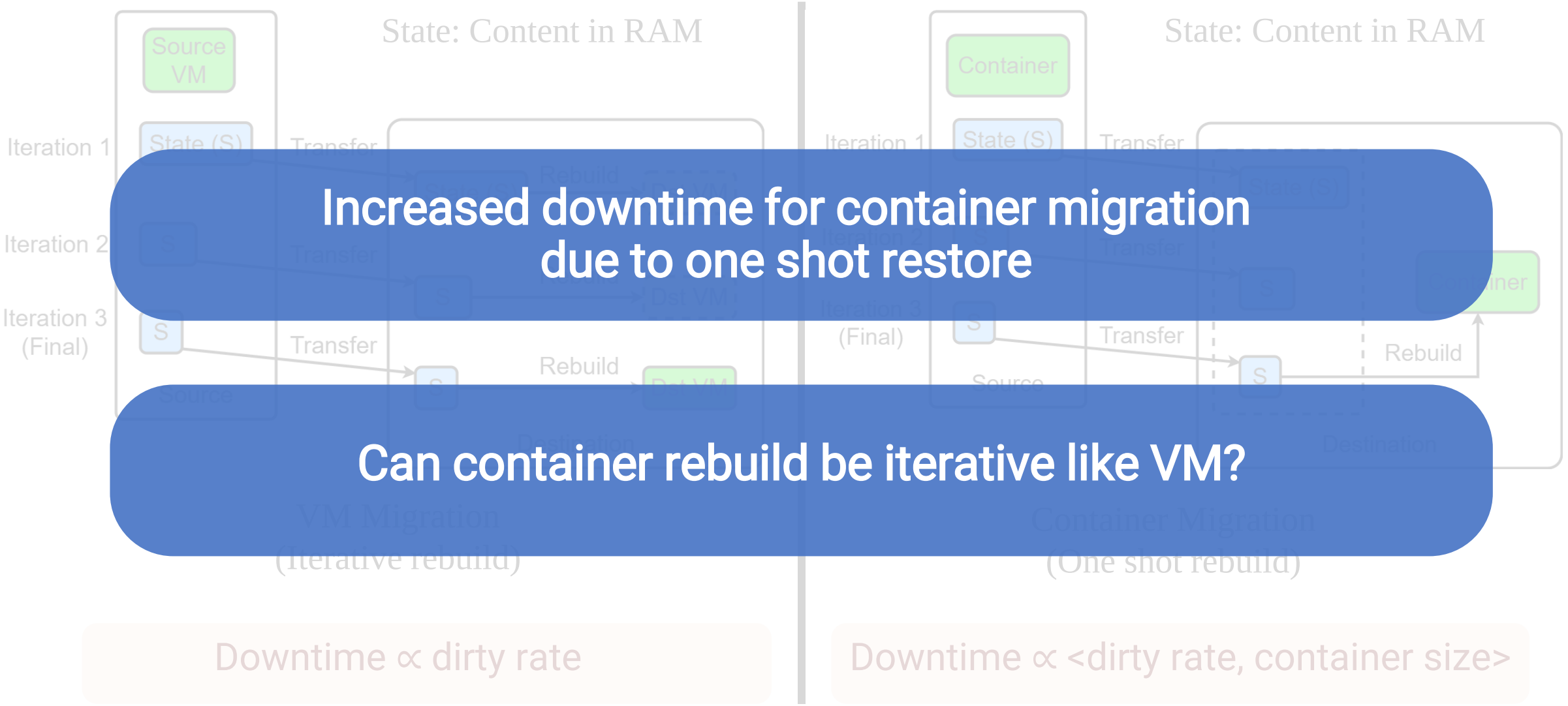

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Can container rebuild be iterative like VM?

Iterative State Rebuild: VM Migration

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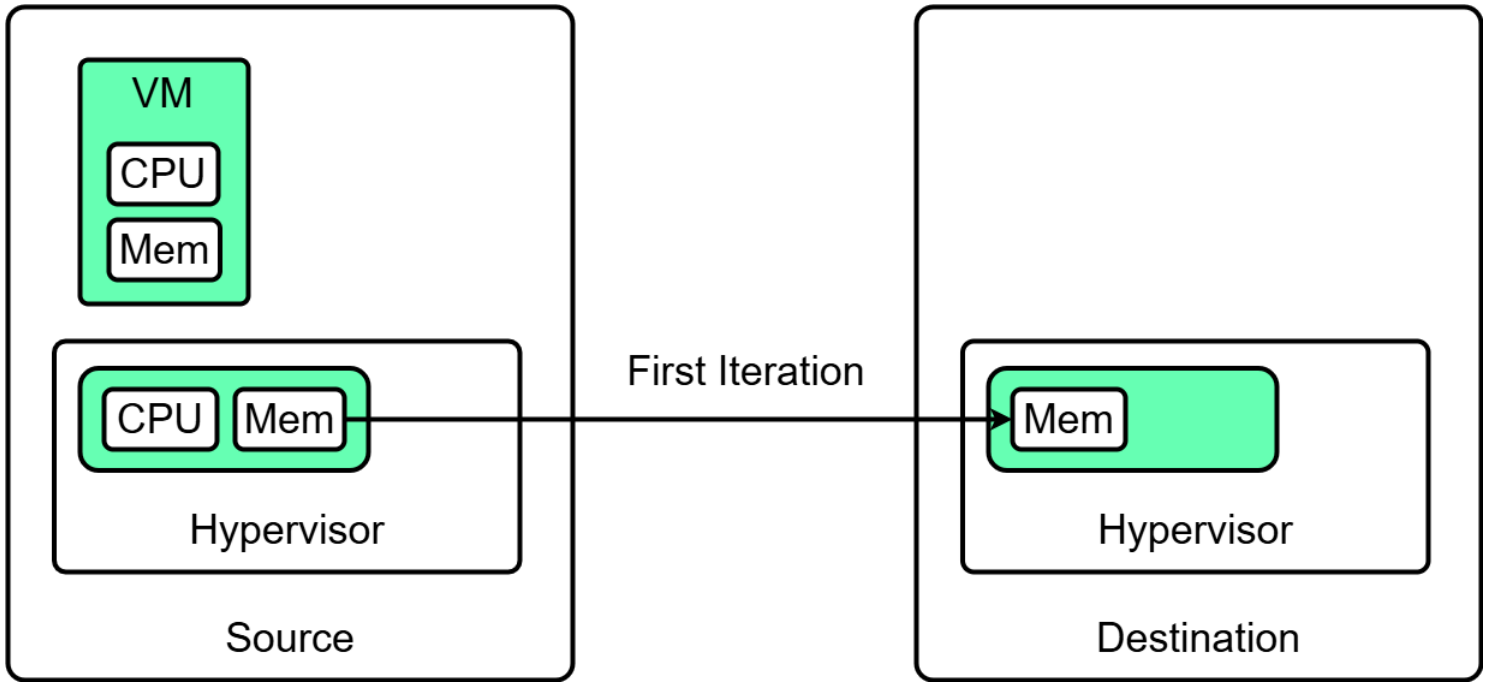

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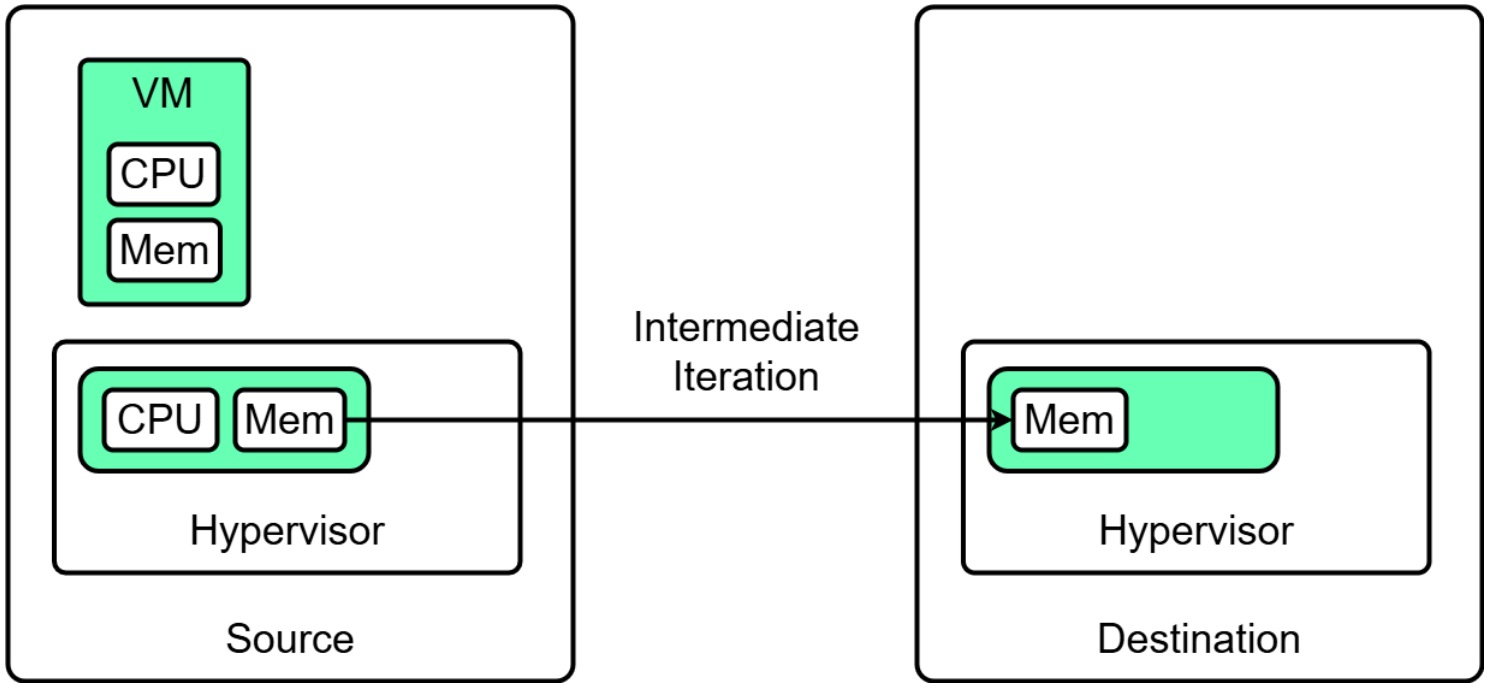

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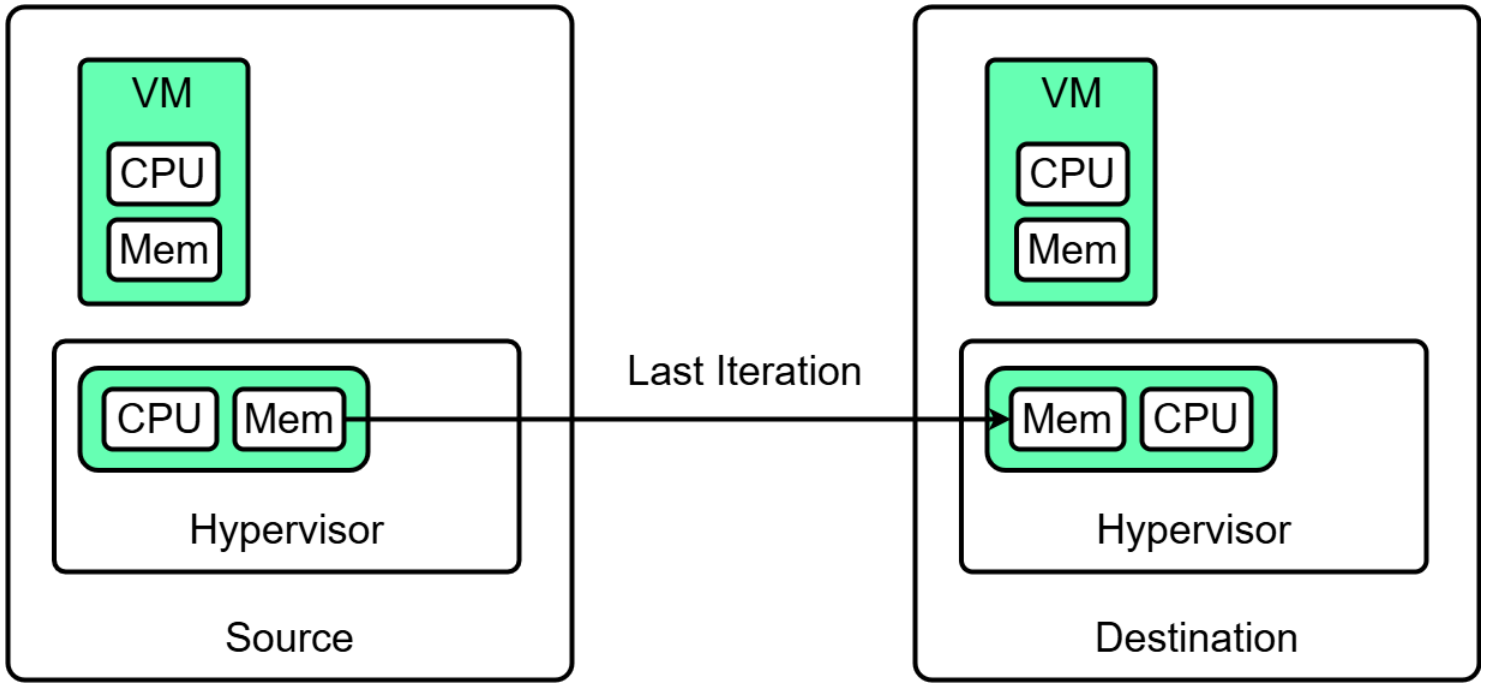

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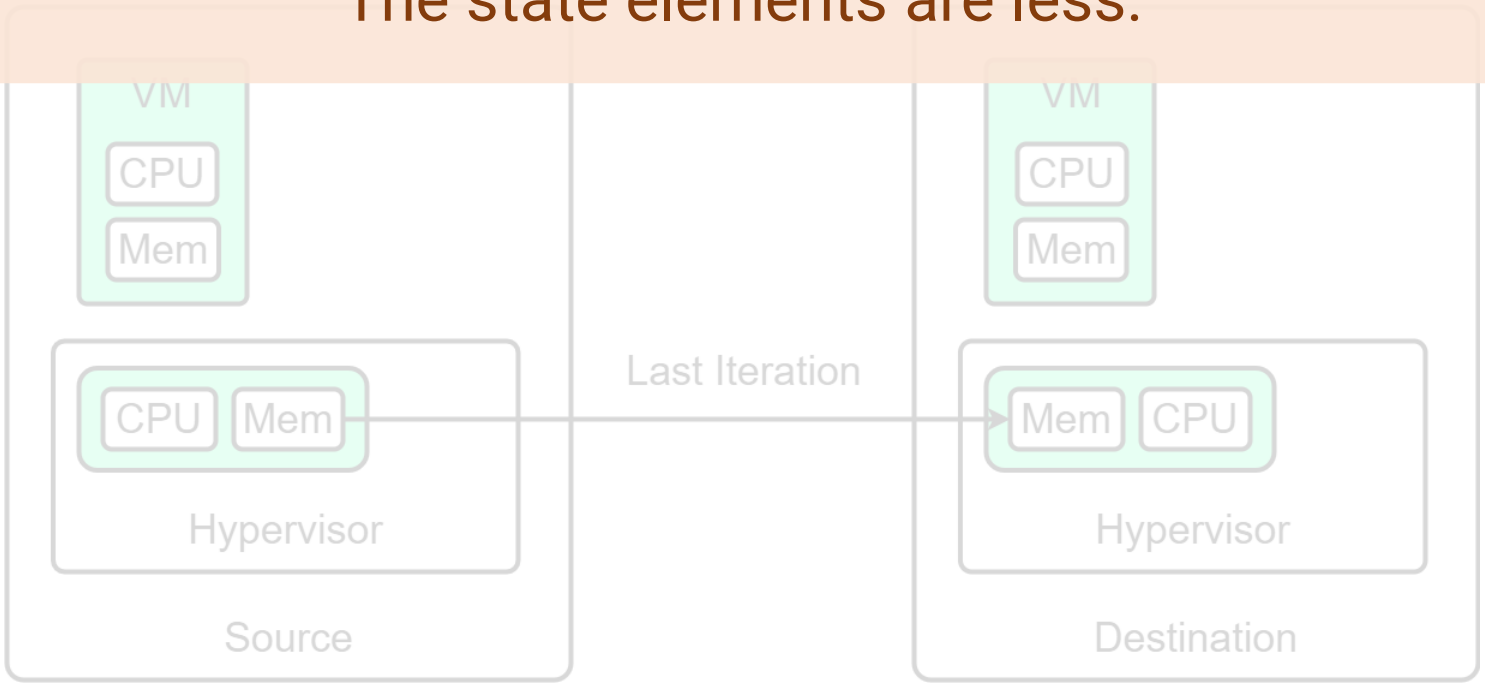

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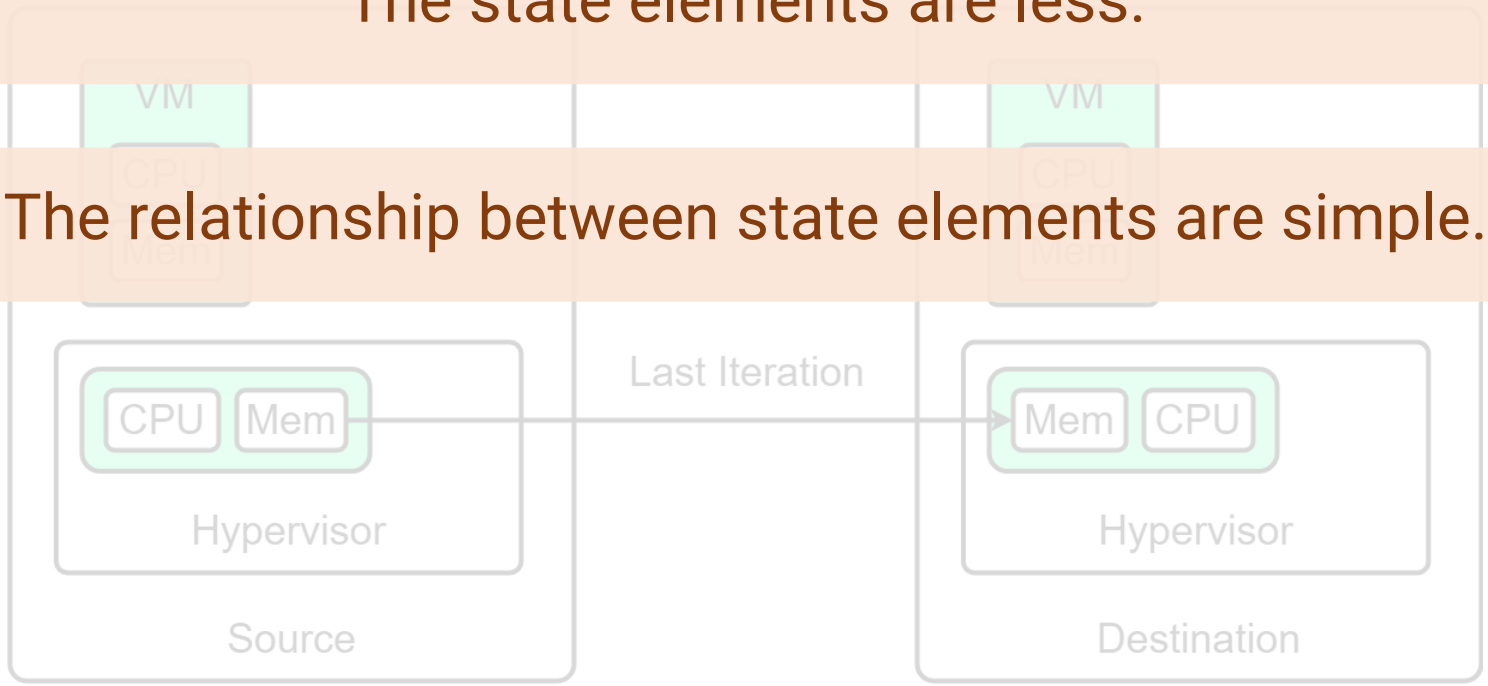

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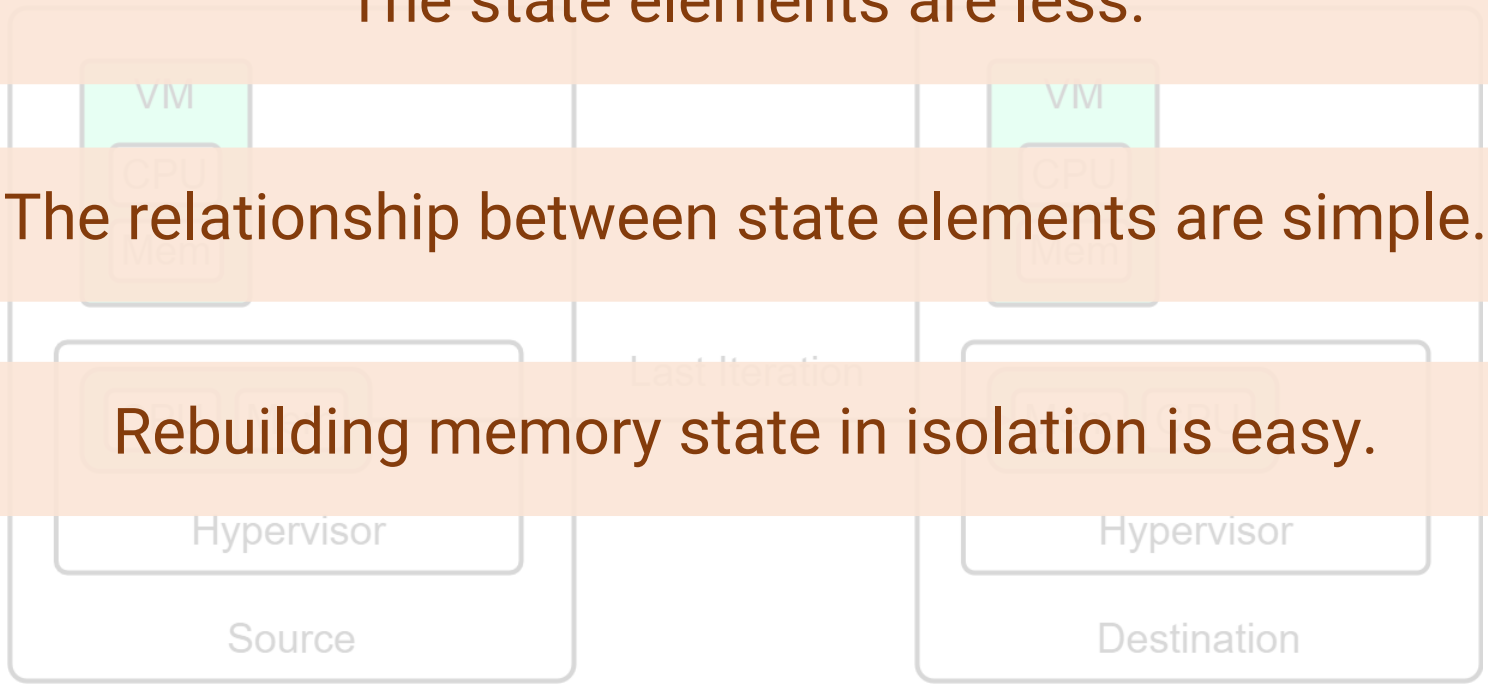
Rebuilding memory state in isolation is easy.



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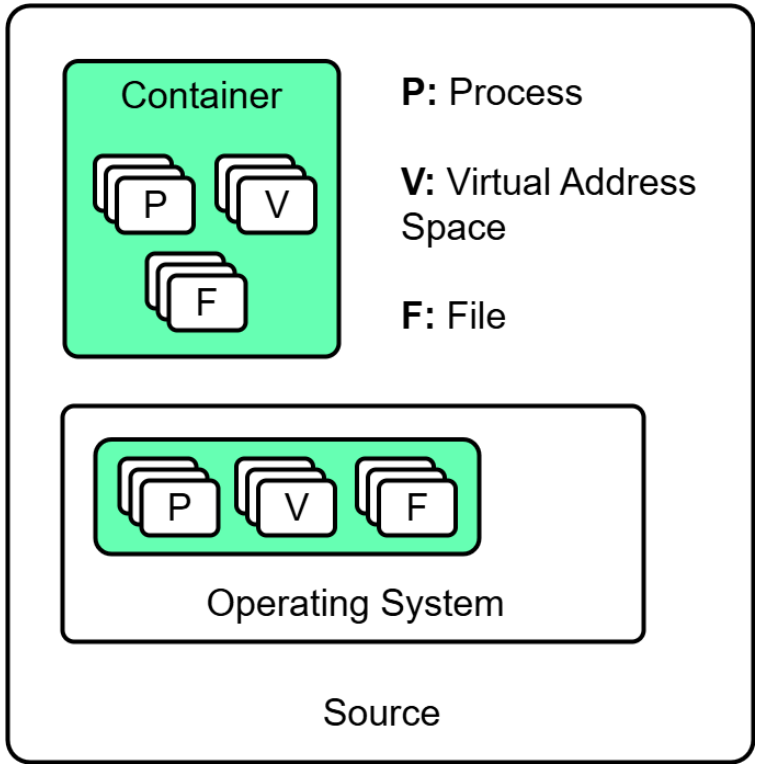

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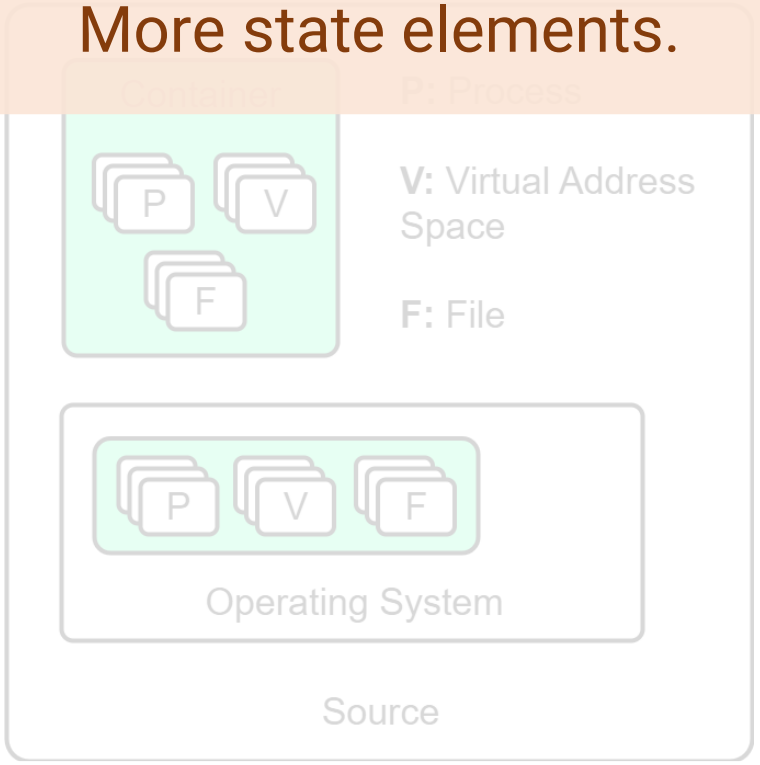

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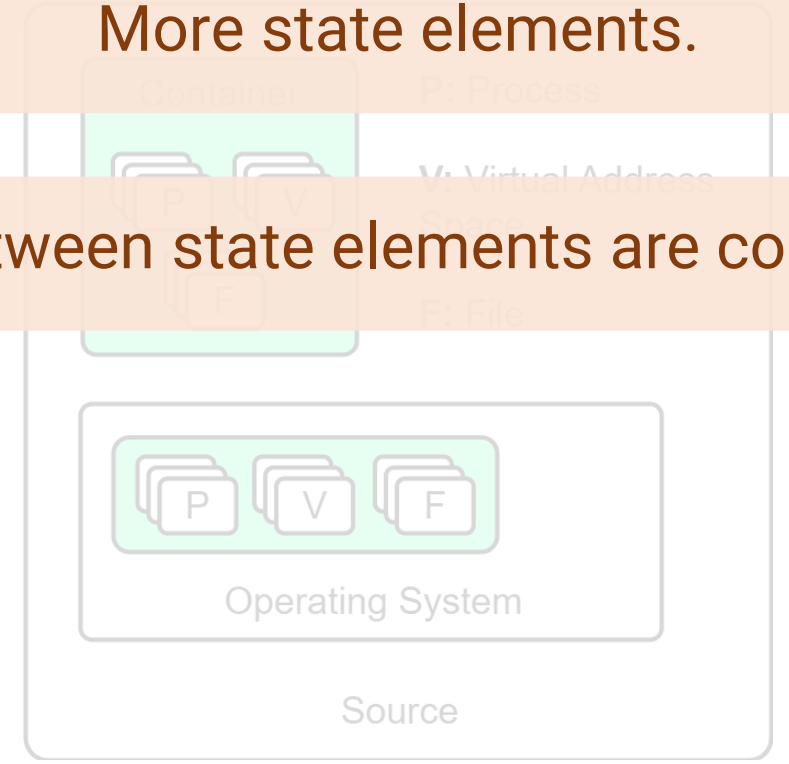

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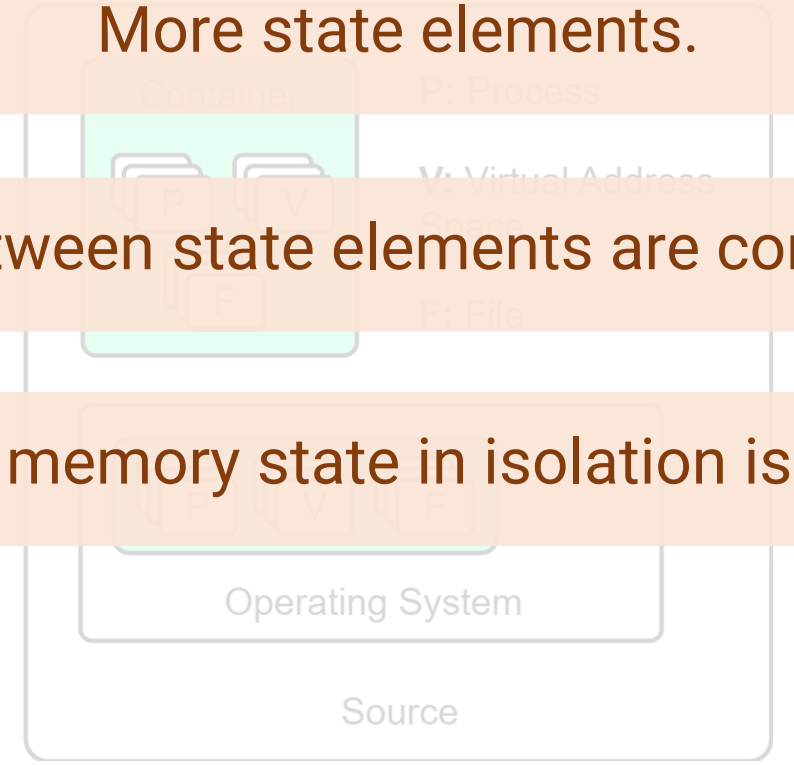

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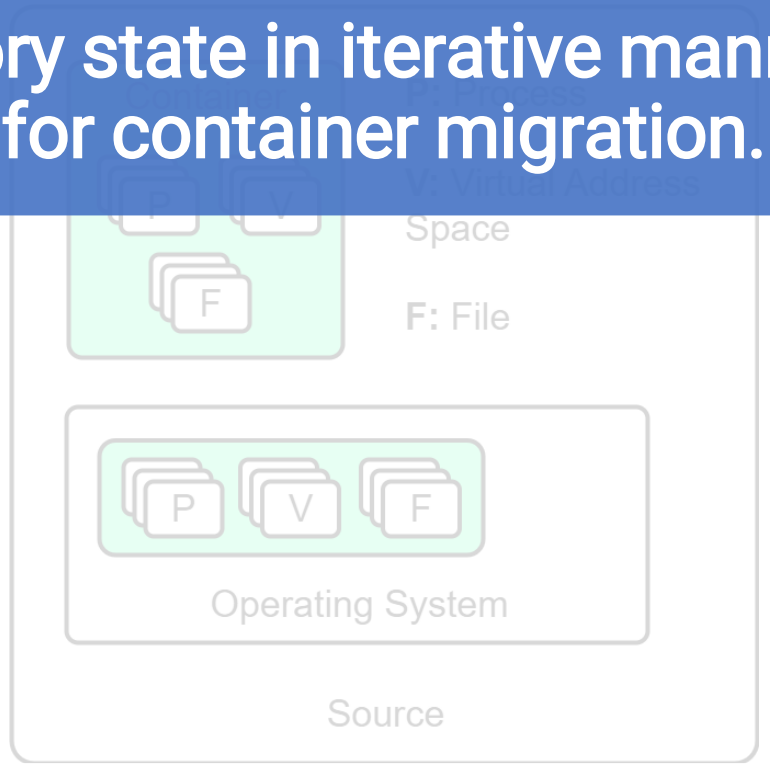

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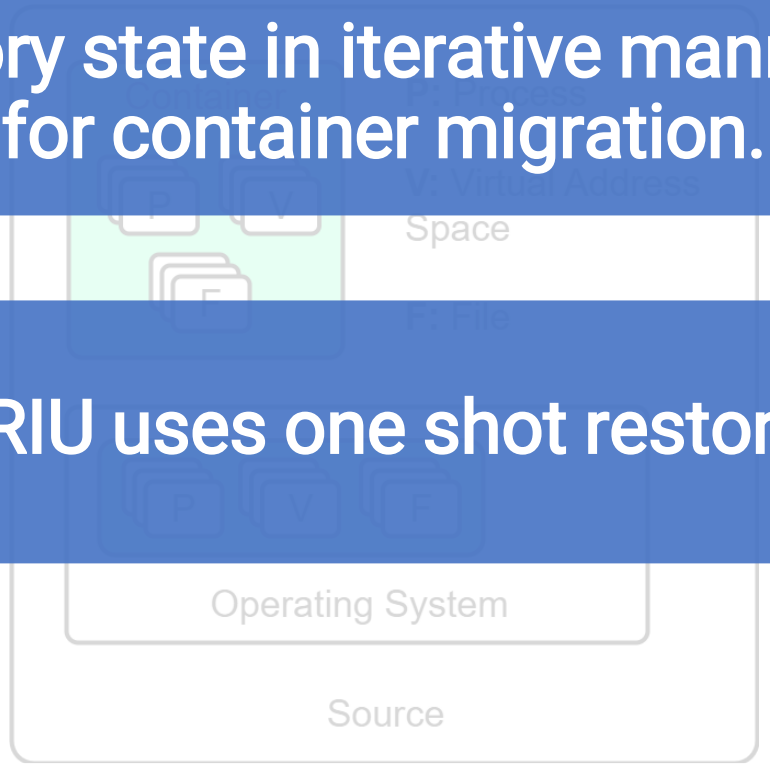

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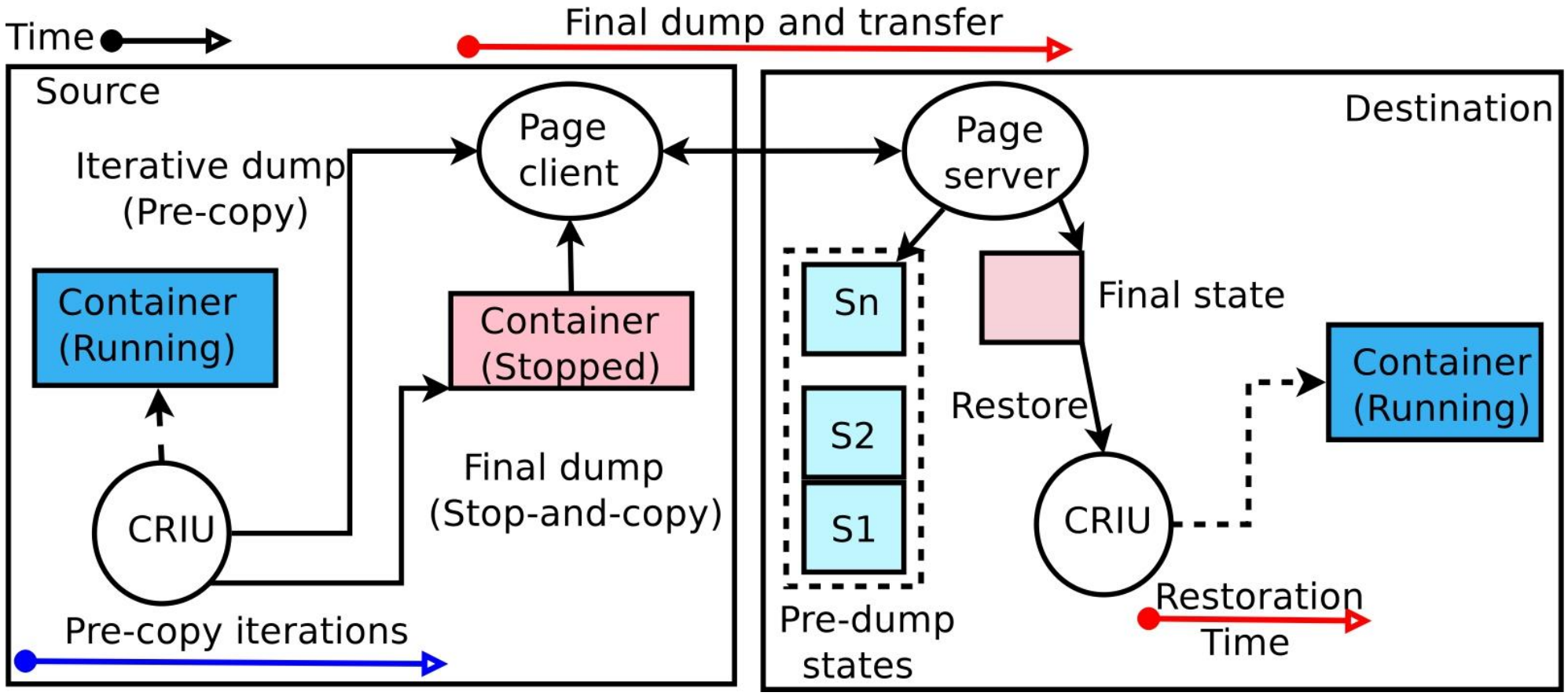

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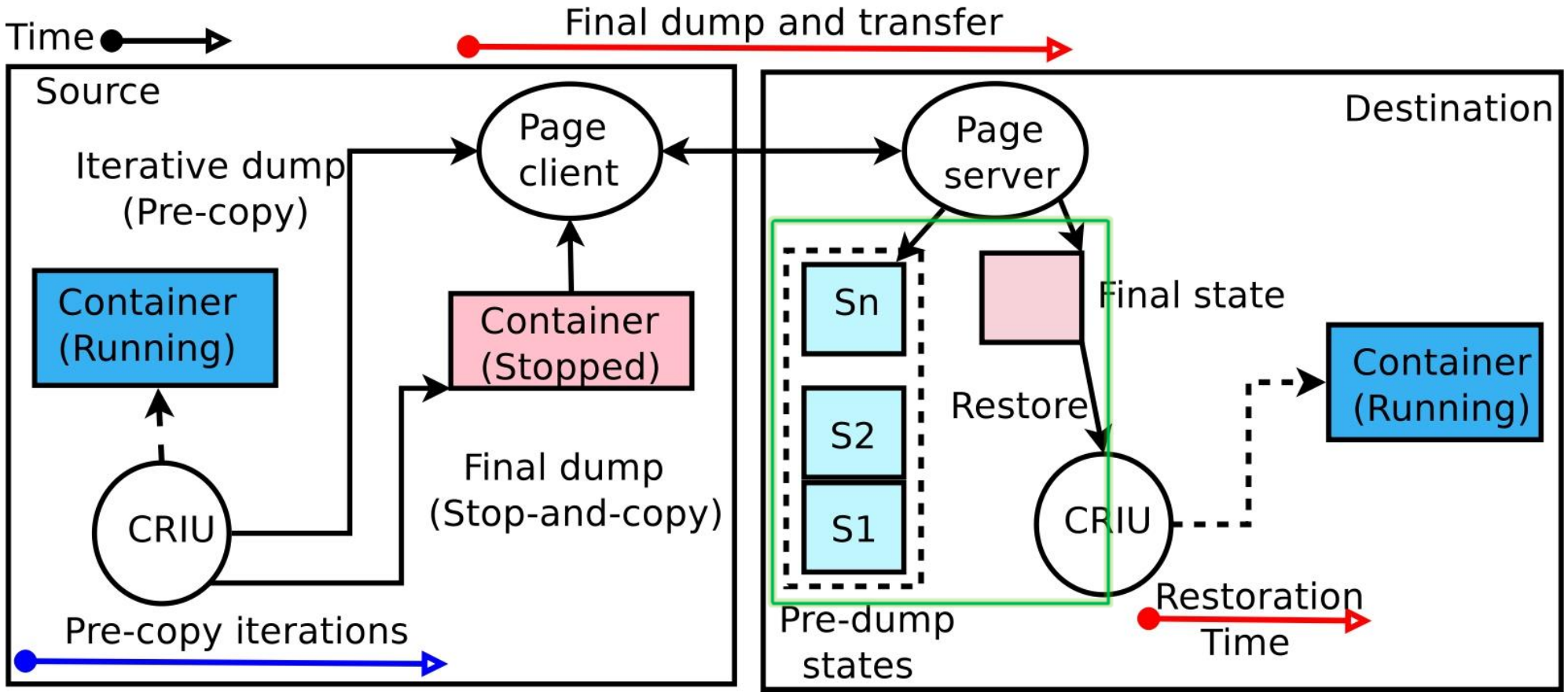

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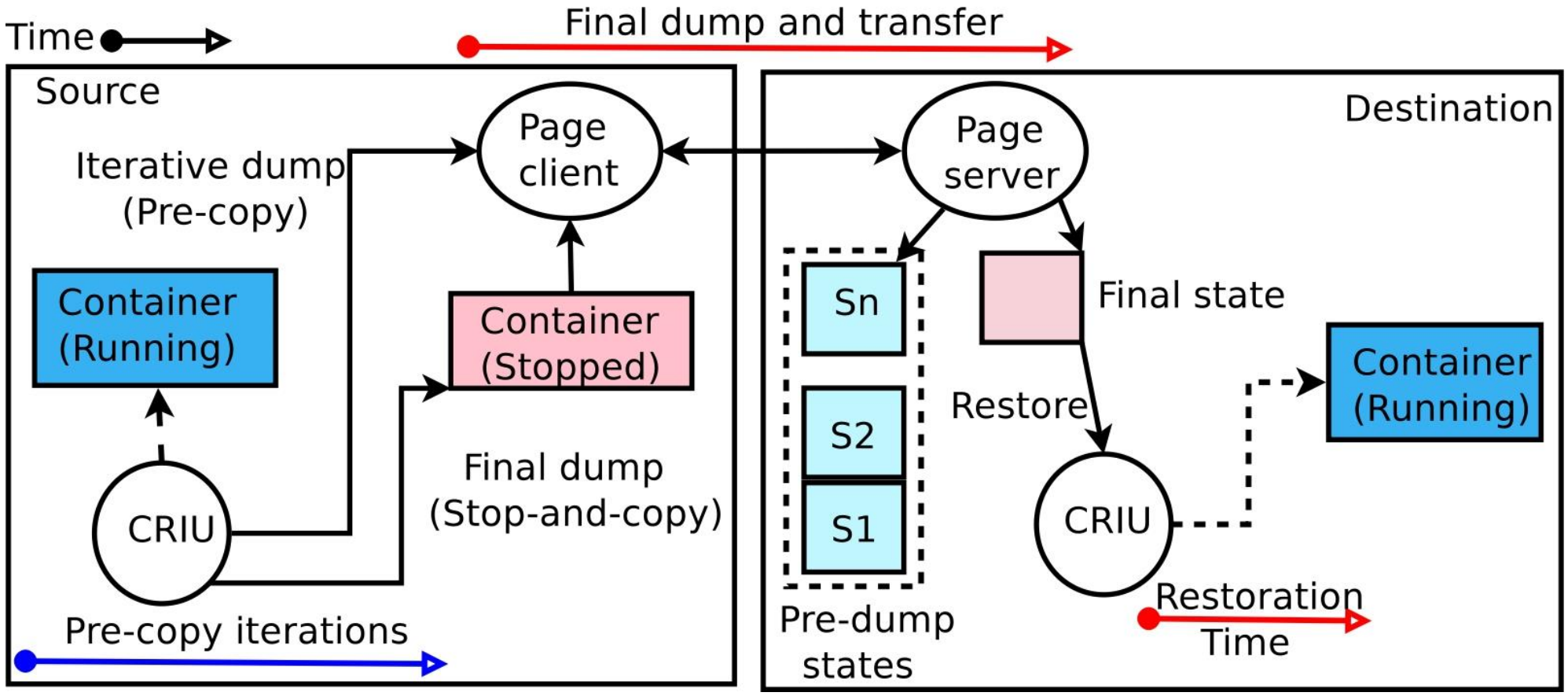
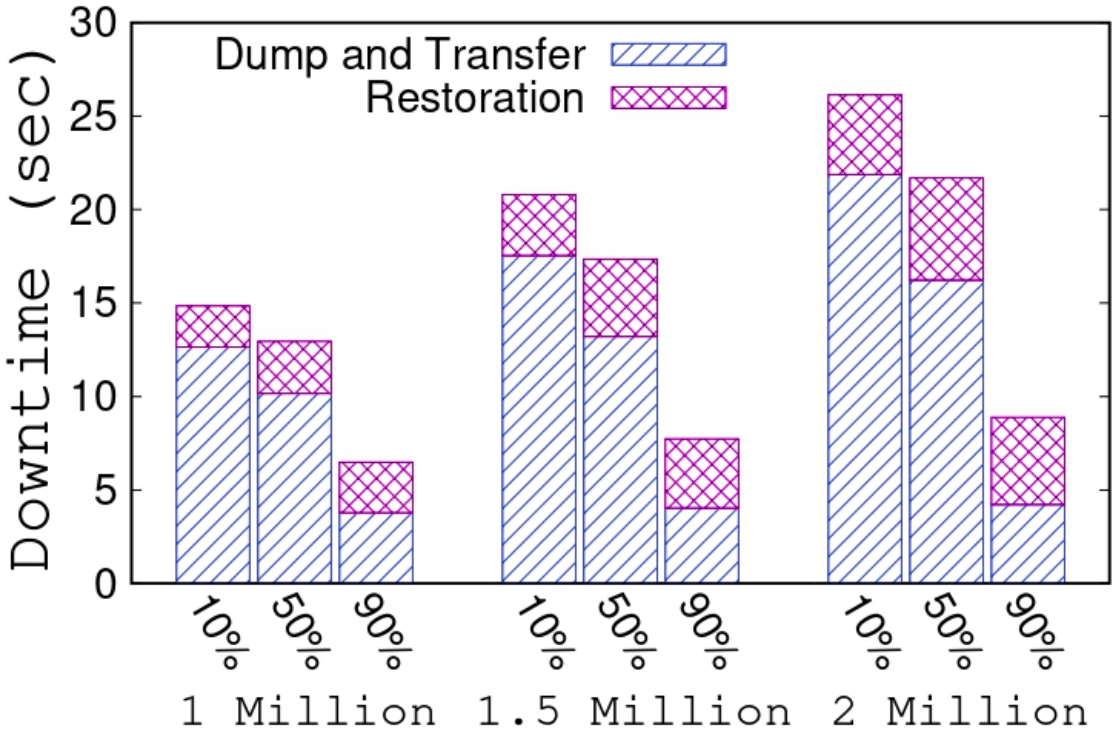


- Downtime = Final Dump and Transfer Time + Restoration Time

Downtime: Restoration Technique Matters!

- **Setup:** Live migration with container running Redis workload with YCSB for different records and read to write ratio.



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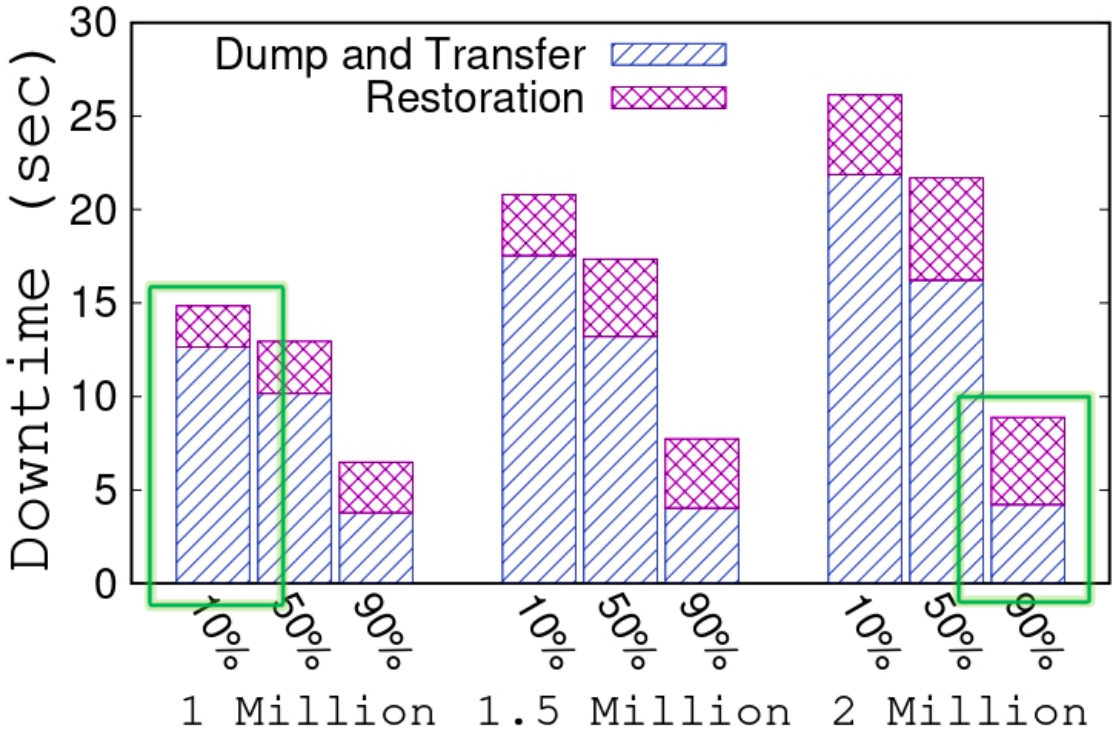

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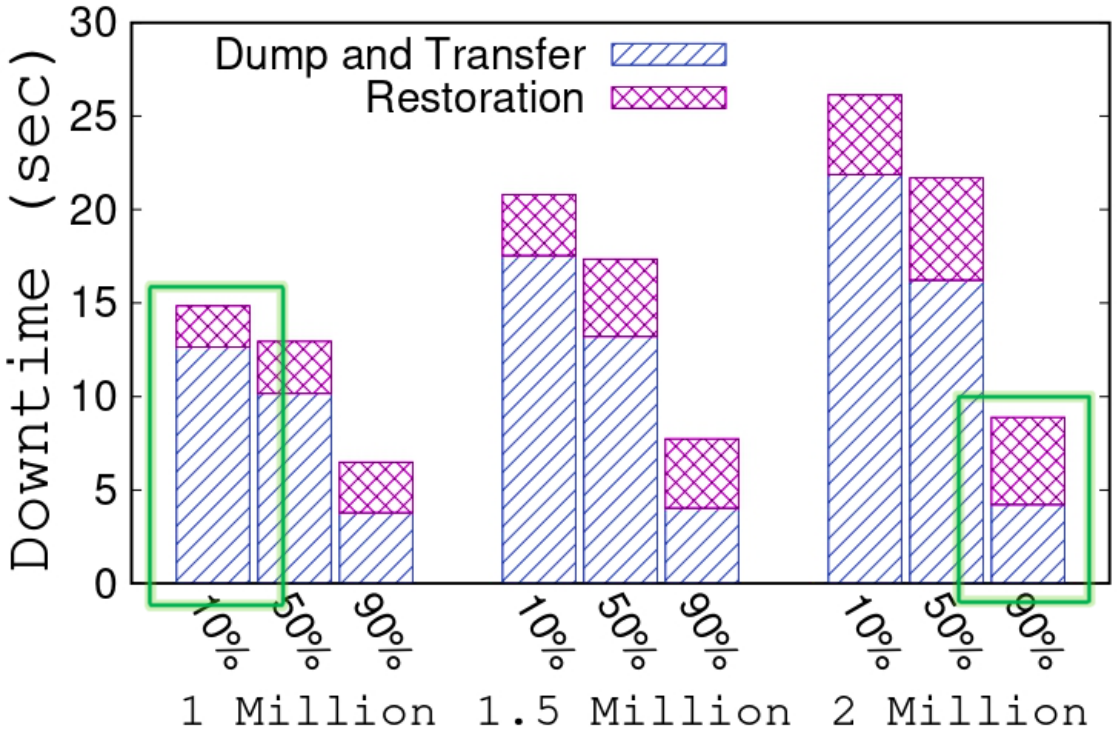

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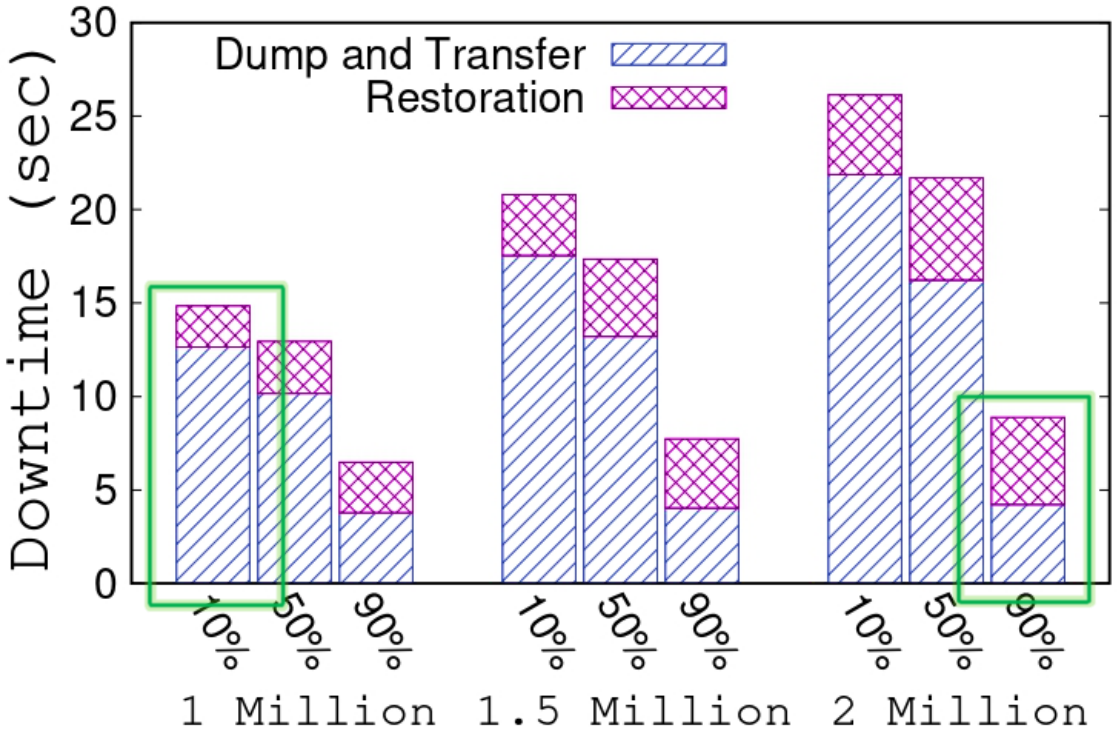
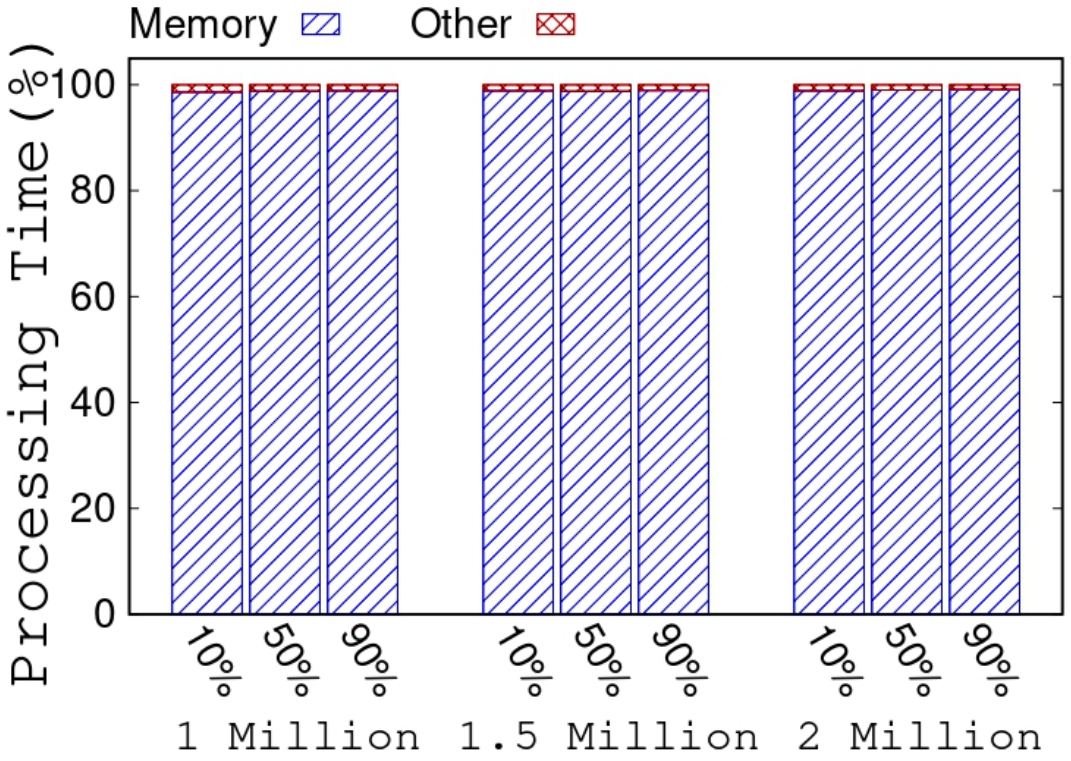


Split Cost of Downtime

Restoration has non trivial contribution towards downtime

Restoration: Significance of Memory State

- Memory state processing dominates restoration time (99.5%) across all settings.



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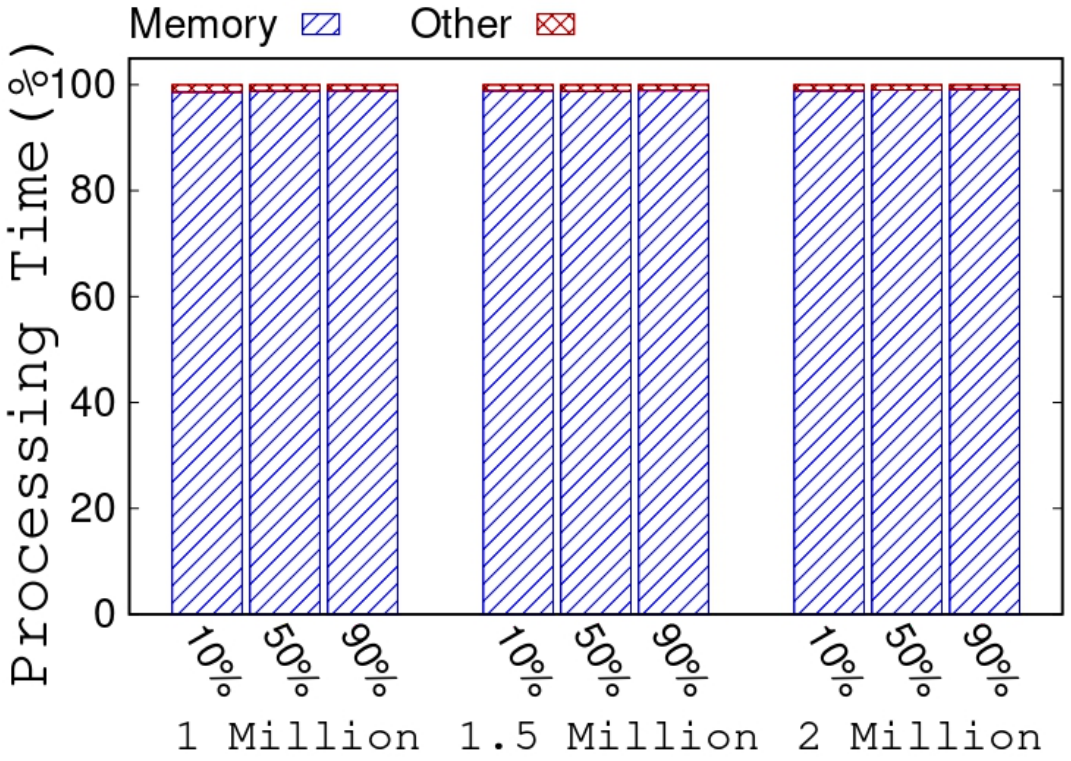

Restore processing cost for memory and others

Iterative rebuild of memory state can significantly improve one shot restore

Contributions

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Iterative Rebuild: Challenges

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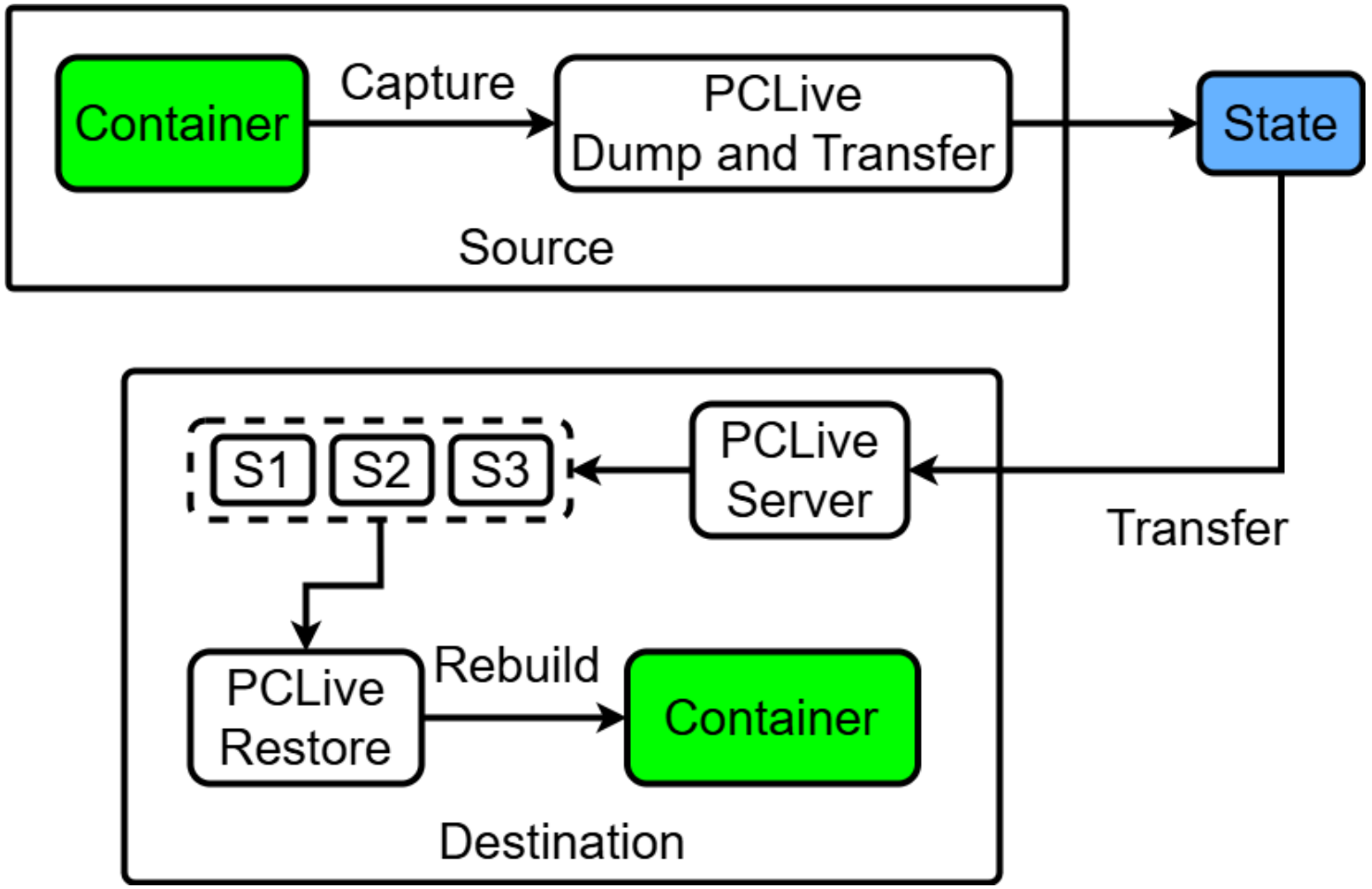
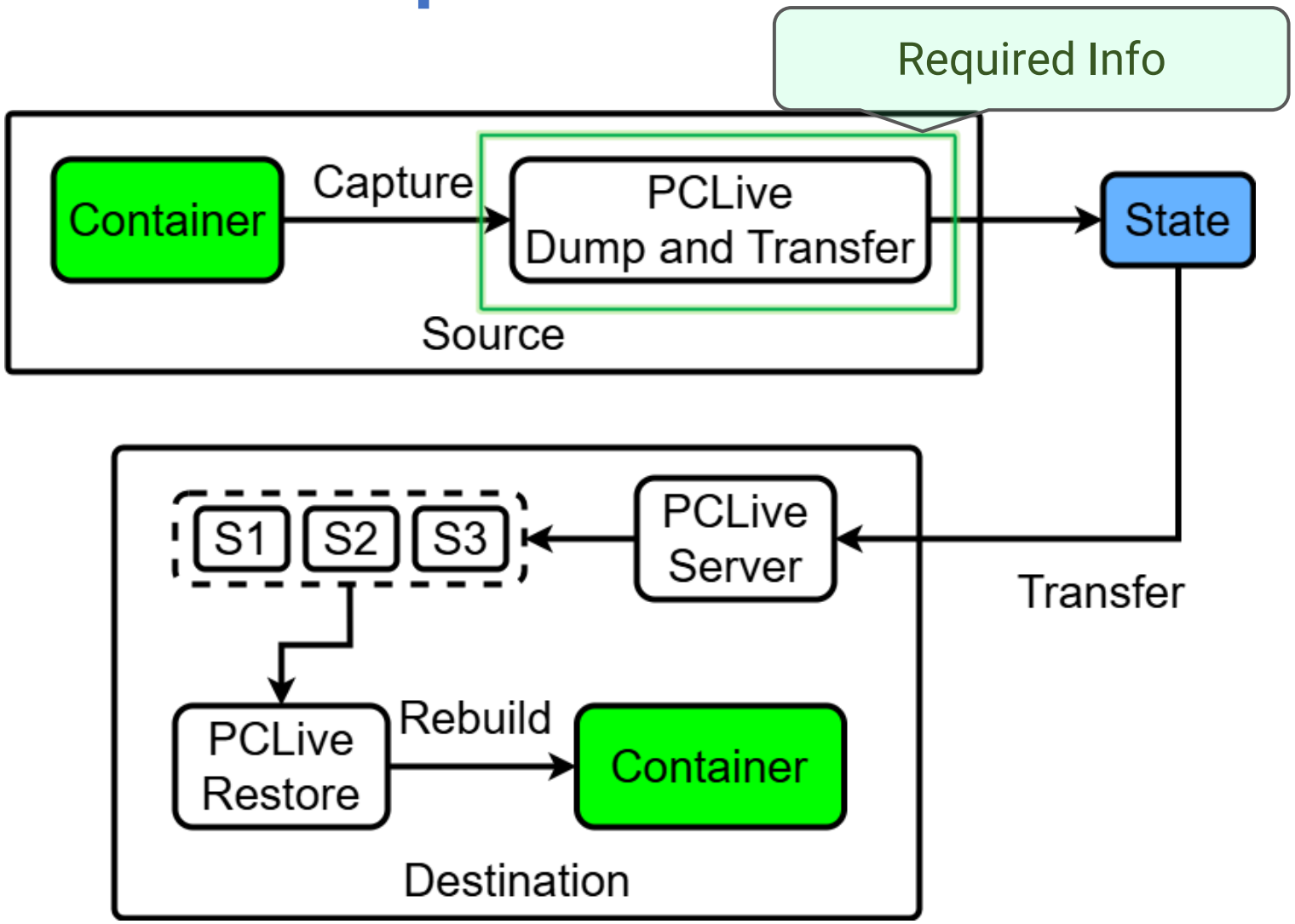
- Maintaining relationship between different states.
- The restoration activity should be non-intrusive and self-aware.
- The resource overheads should be comparable with one shot restore.

PCLive: Design

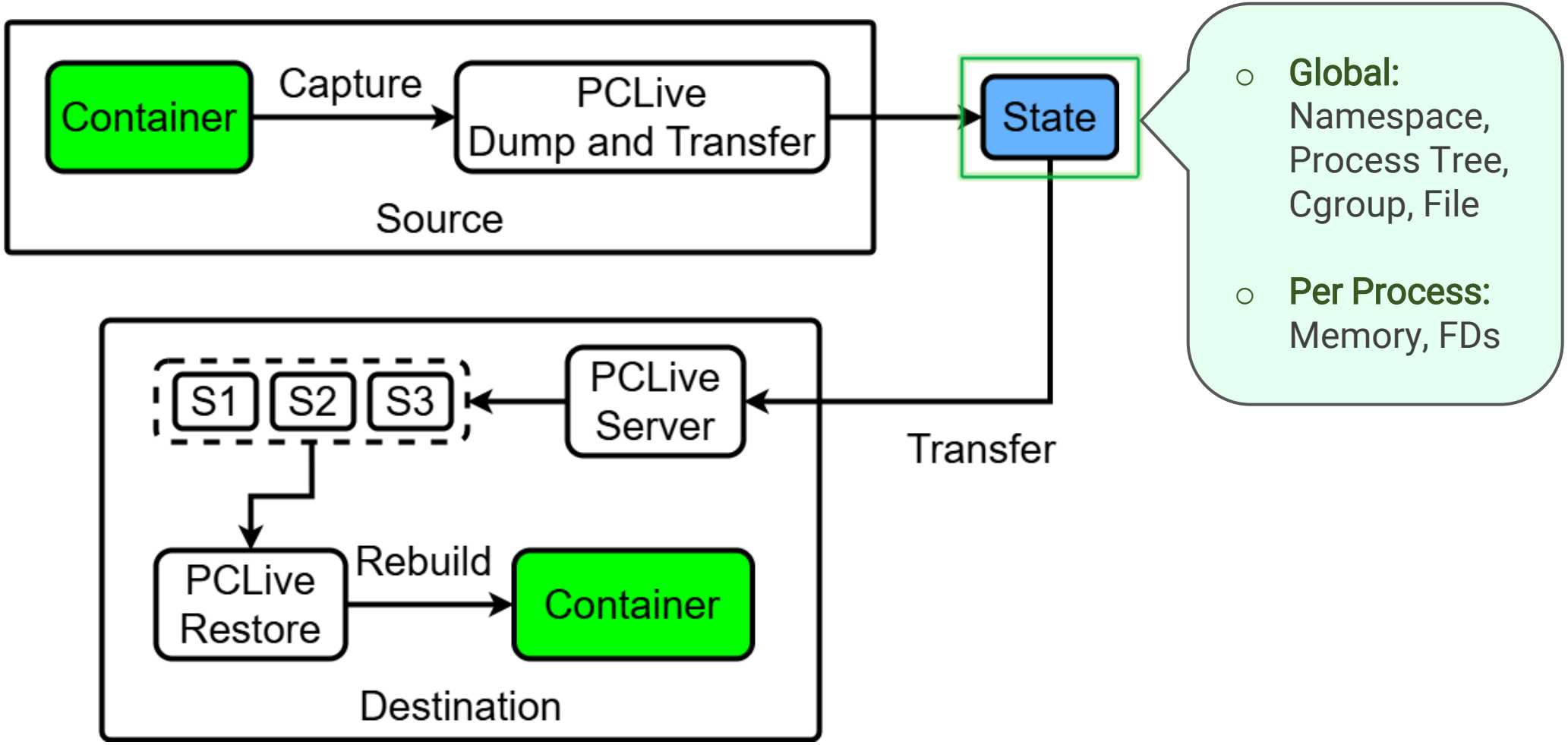


PCLive: Capture and Transfer



- Process Tree, Namespace, File, etc. along with memory mapping and its content.
- PCLive is configured to dump any sub-system.
- The freeze time has to be minimum.

PCLive: State



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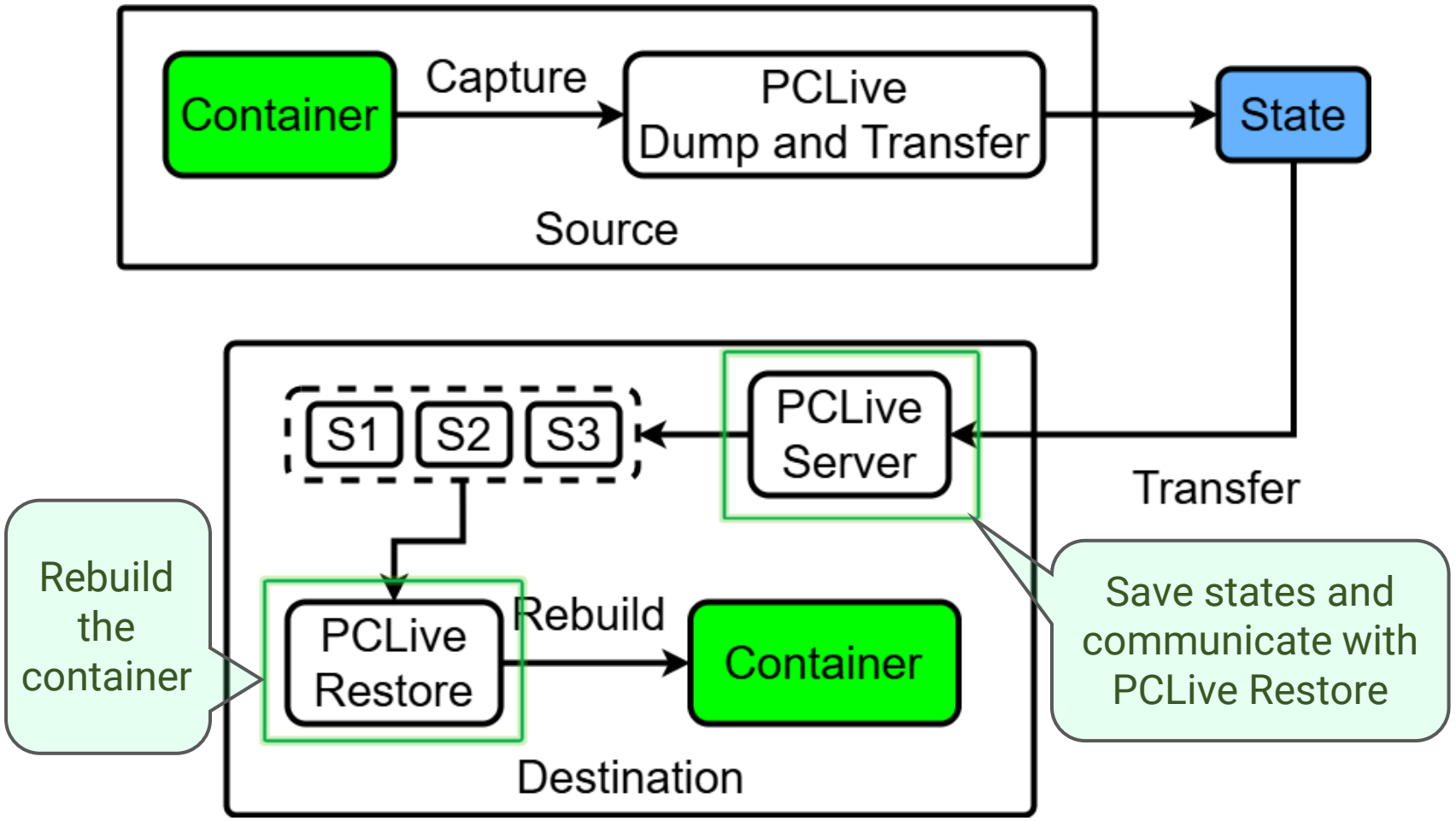
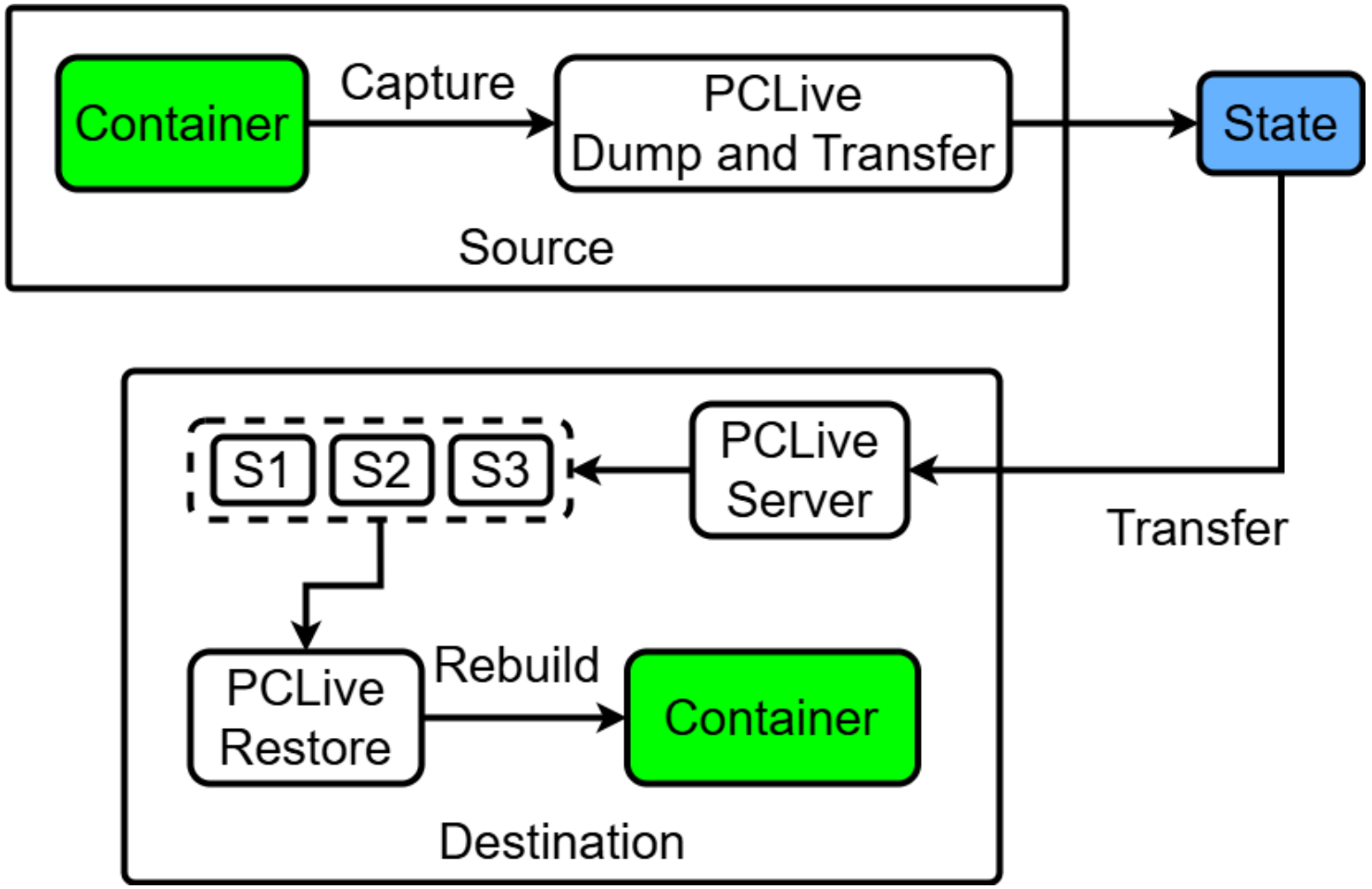


- The restore can be started after any iteration (Delayed Restoration).
- Restore can be triggered after receiving global states (PCLiveG).

PCLive: Implementation



- Modified CRIU and runC to achieve pipelined restore.

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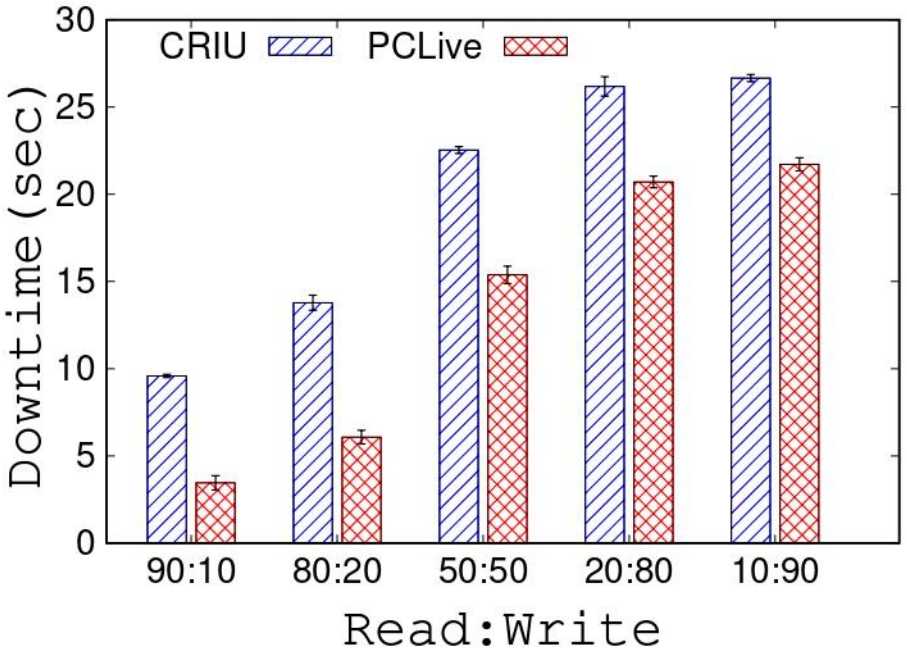
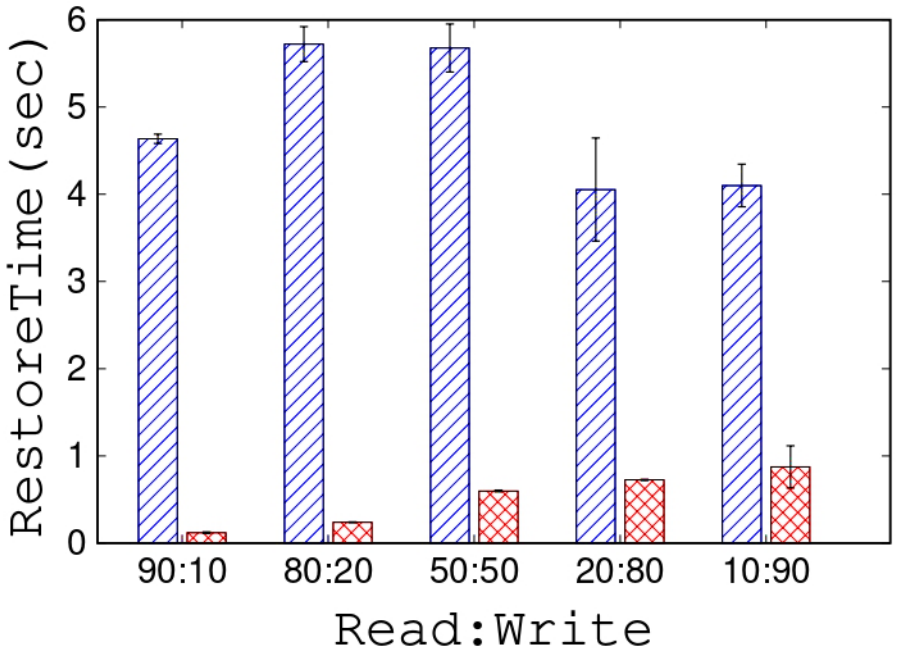
PCLive: Downtime Reduction





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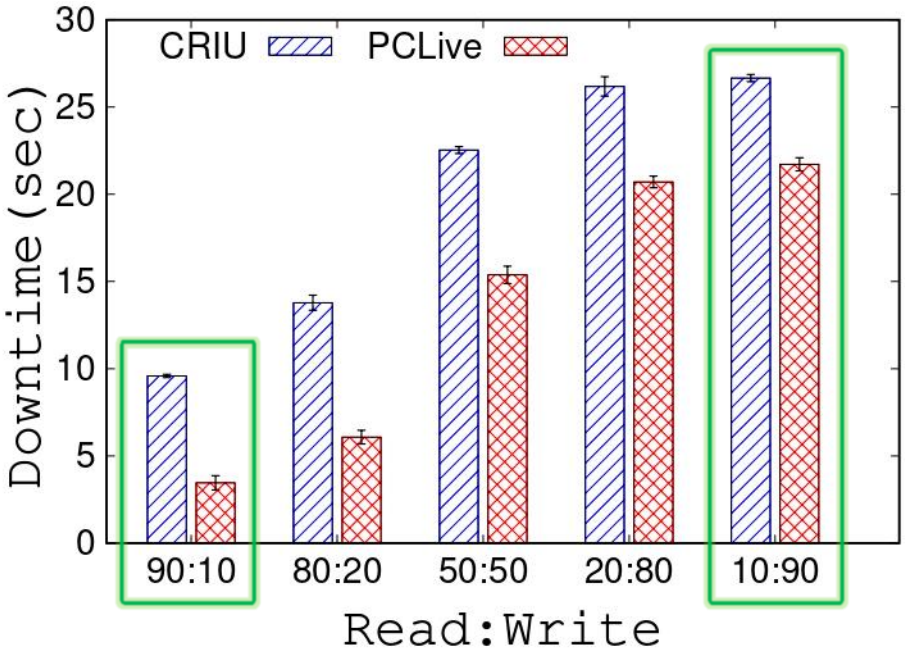
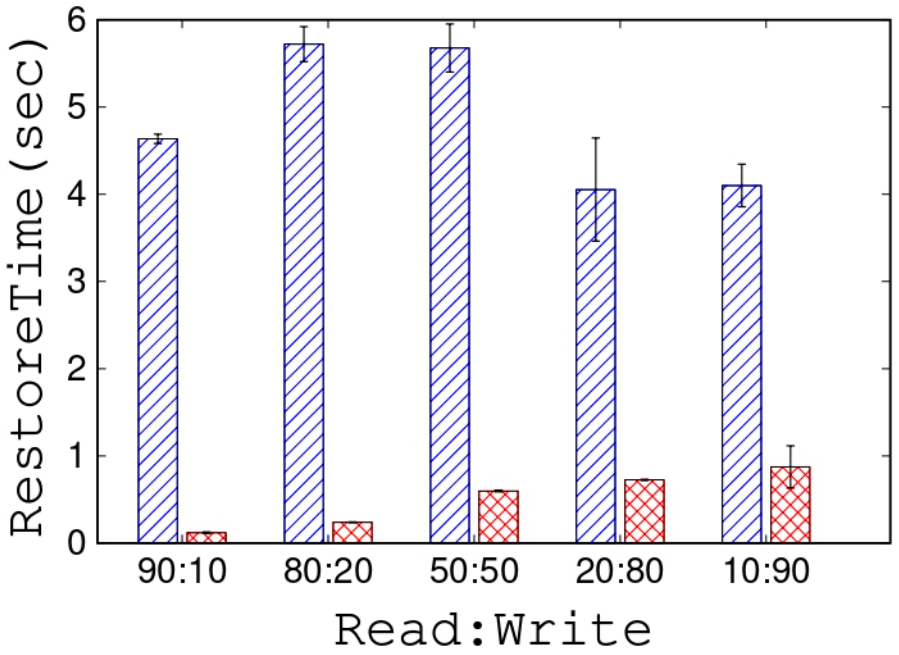
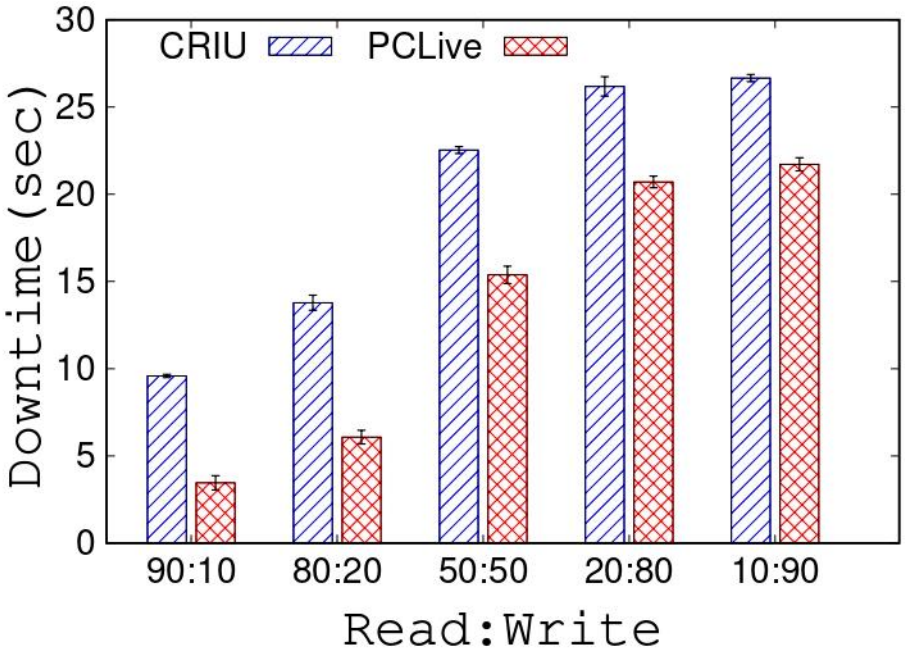
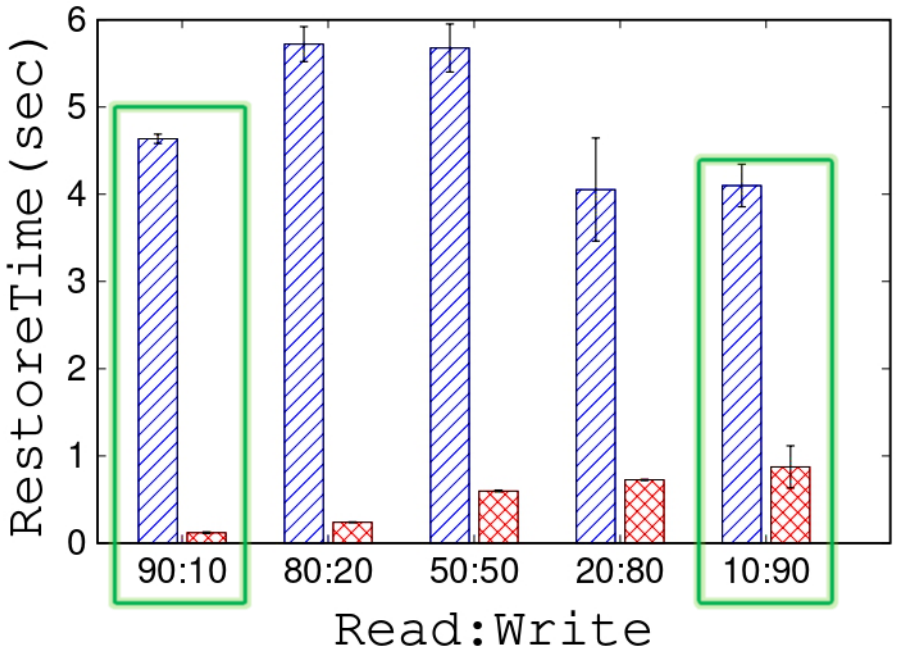




- Setup: Redis workload with YCSB for 2M records and different read to write ratio.
- Service downtime: 2.7x reduction for read intensive, 18% reduction for write intensive.

PCLive: Downtime Reduction





- Setup: Redis workload with YCSB for 2M records and different read to write ratio.
- Service downtime: 2.7x reduction for read intensive, 18% reduction for write intensive.
- Restore time: 38x reduction for read intensive, 5.4x reduction for write intensive.

Contributions

- Empirically motivate the requirement to improve the restoration process for container migration.
- Identify and address the challenges to design and implement iterative rebuilding using PCLive.
- Demonstrate the benefits of PCLive in terms of downtime reduction.
- Showcase the flexibility of PCLive to find a sweet-spot for resource overhead and downtime tradeoff.

PCLive: CPU & Memory Utilizations

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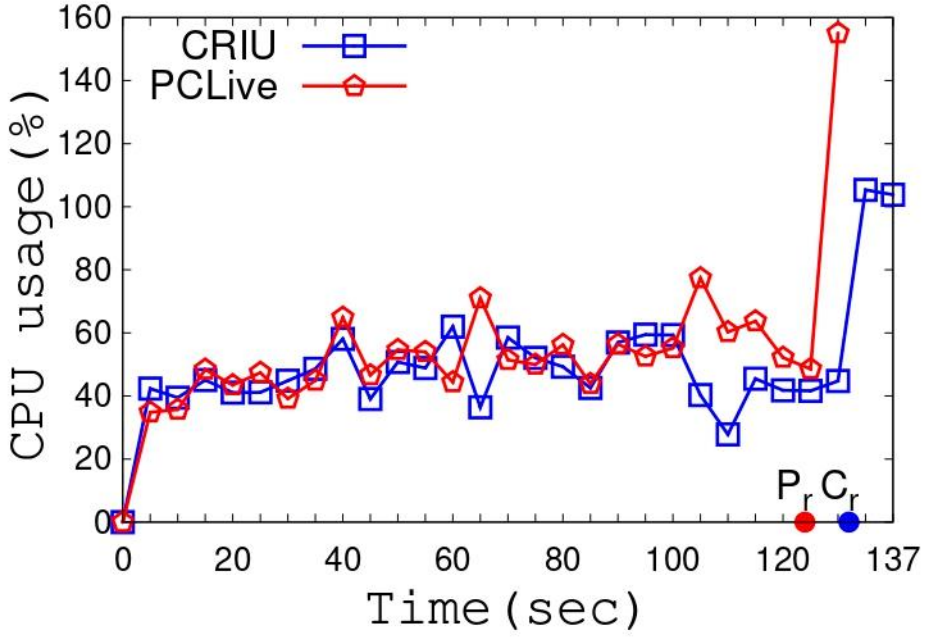

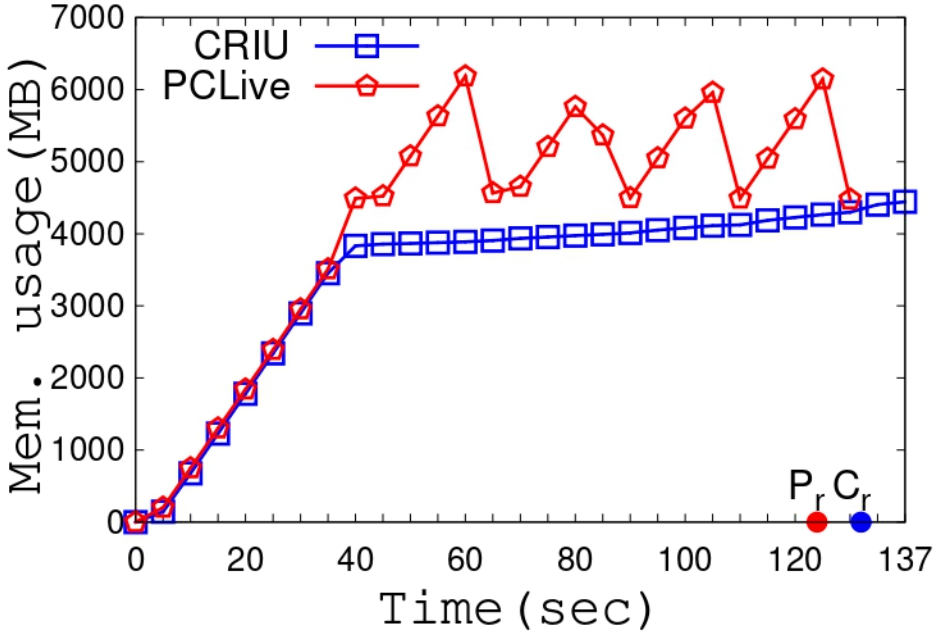

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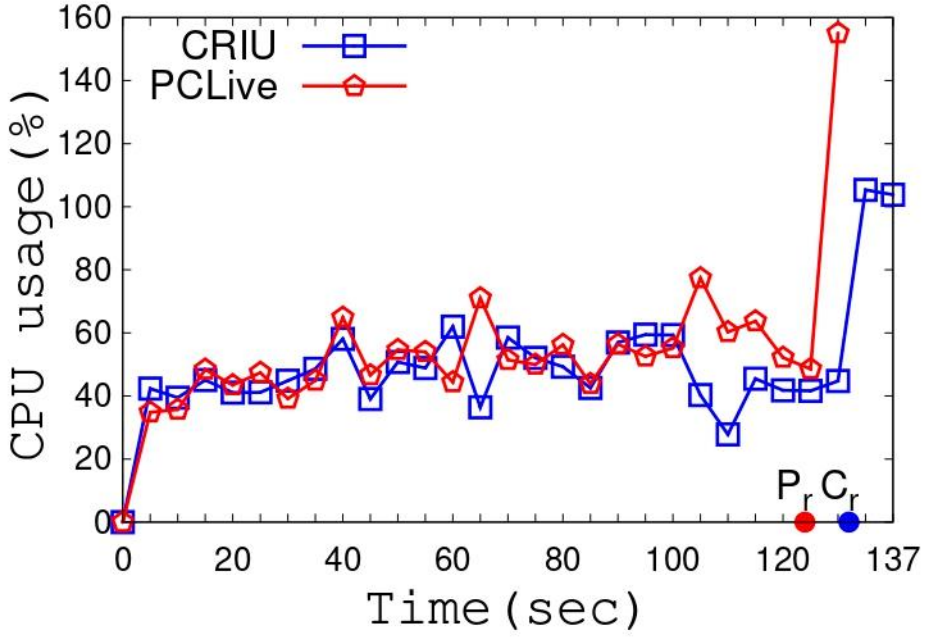

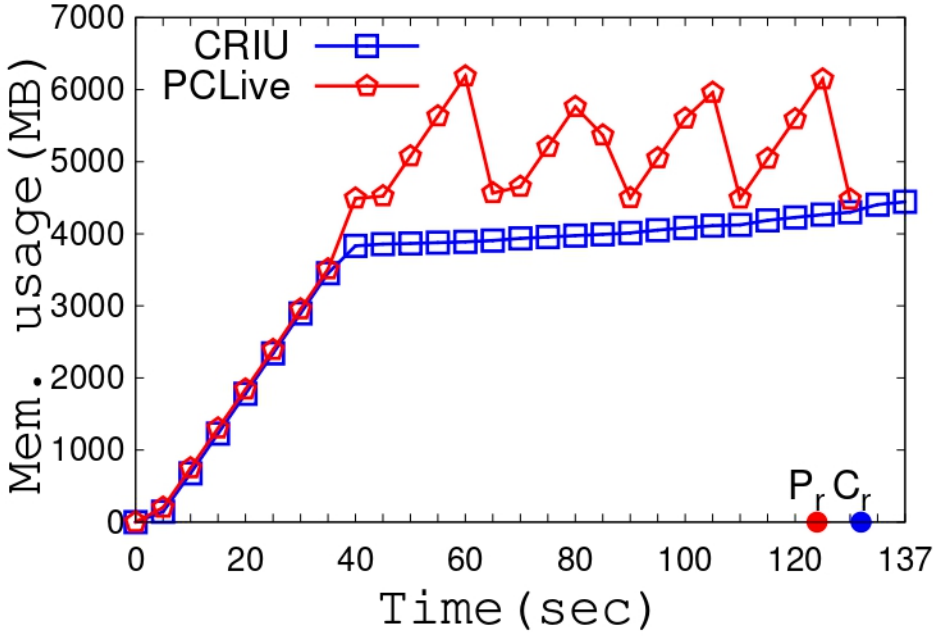

- Setup: Write intensive (10% Read) Redis workload with YCSB for 2M records.
- CPU utilization: 4% more for write intensive, similar for read intensive.
- Memory utilization: 23% more for write intensive, similar for read intensive.

PCLive: Optimizing Memory Overhead

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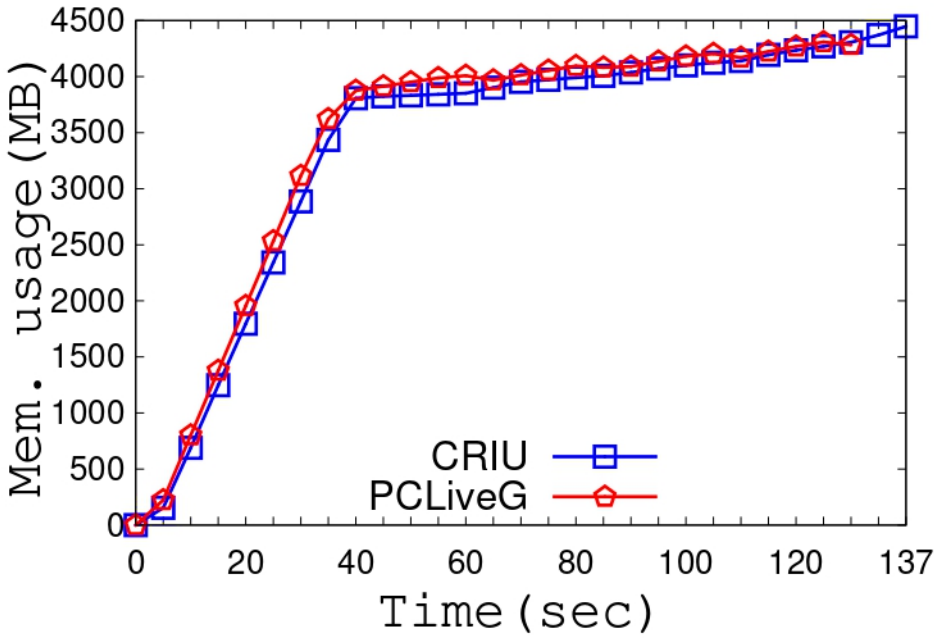

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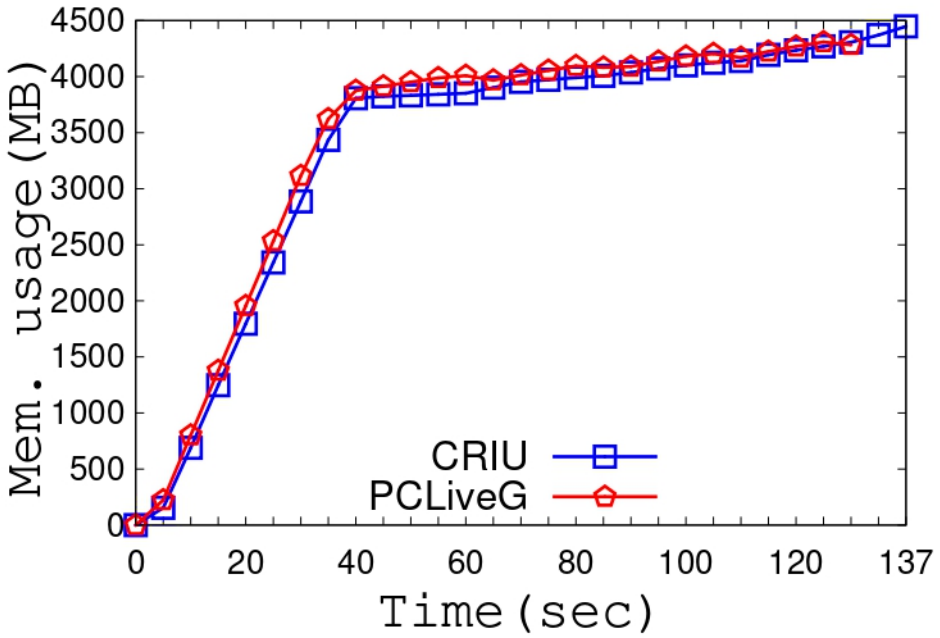

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- PCLiveG: Memory overhead is negligible (~100MB) for write intensive, CPU overhead is 13.5% - 21.8%. Restore time is reduced by more than 200ms.

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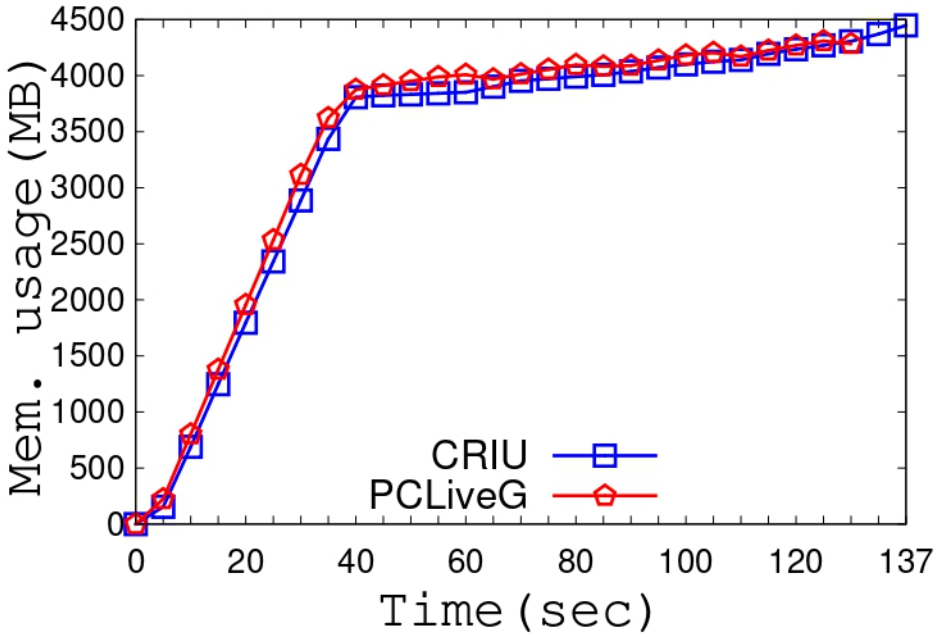

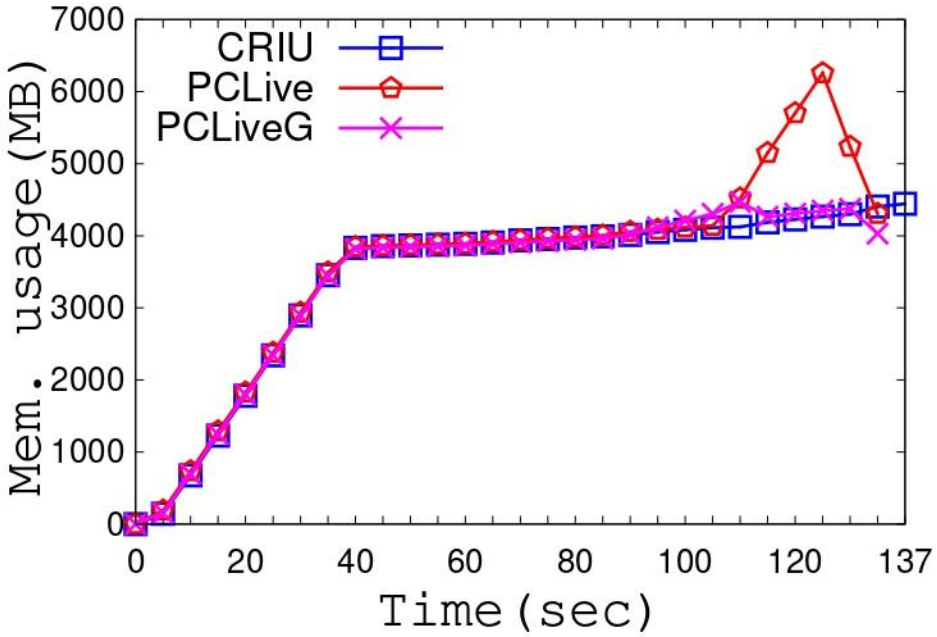

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- Delayed Restoration: Memory overhead is ~5% with similar CPU overheads.

PCLive: Application Throughput

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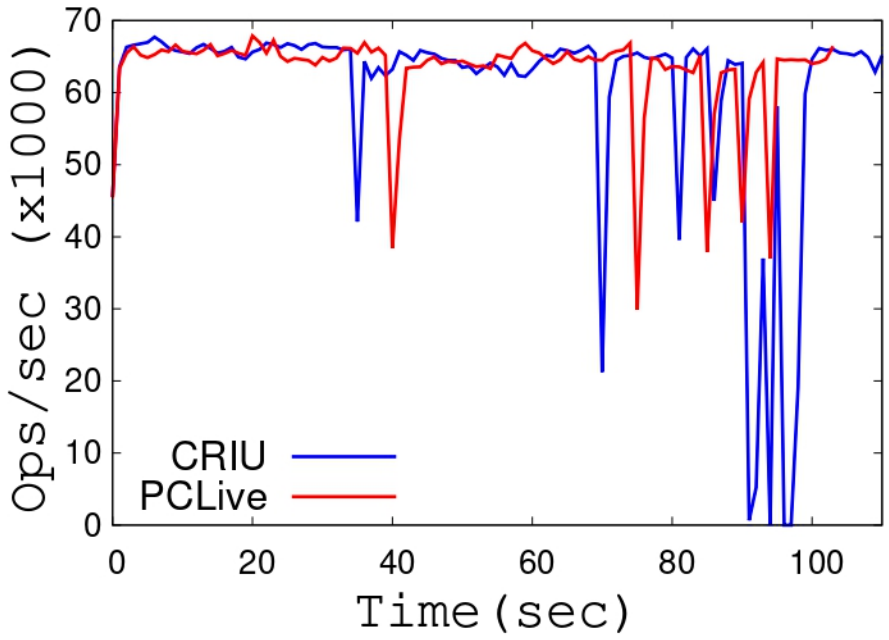

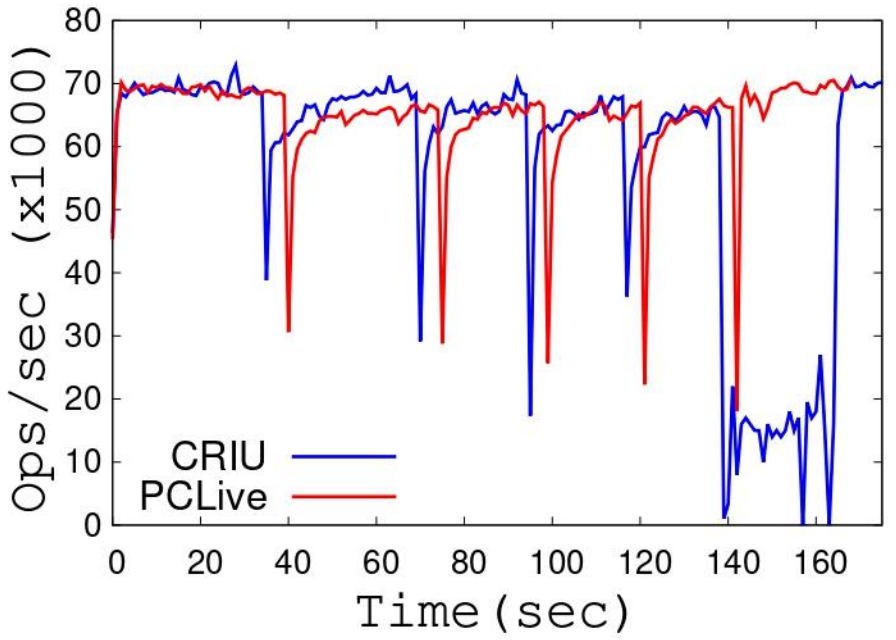

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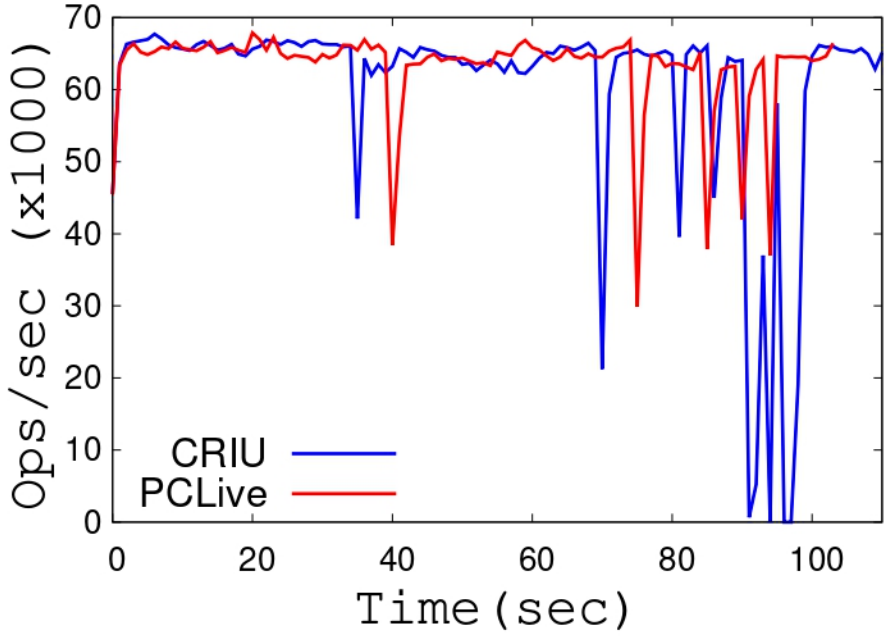

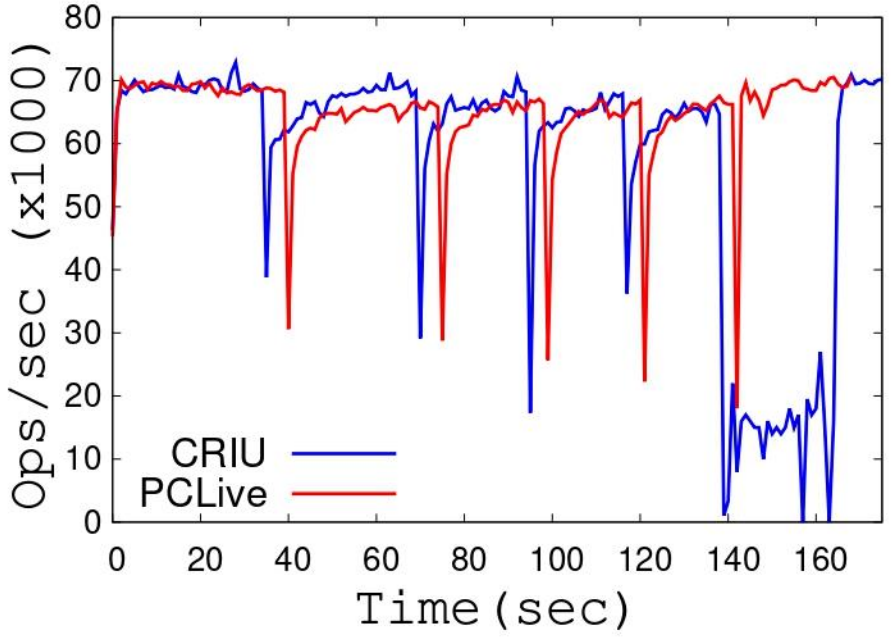

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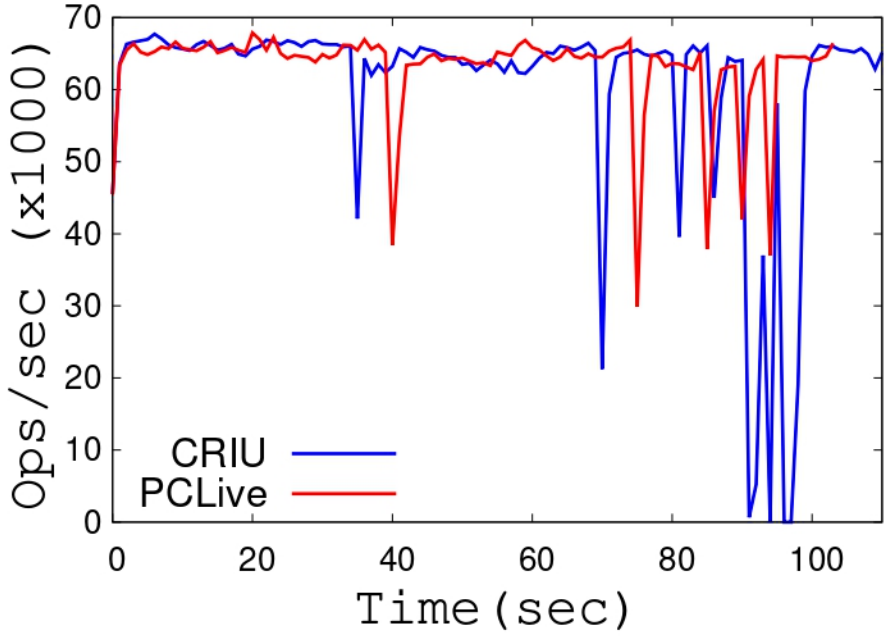

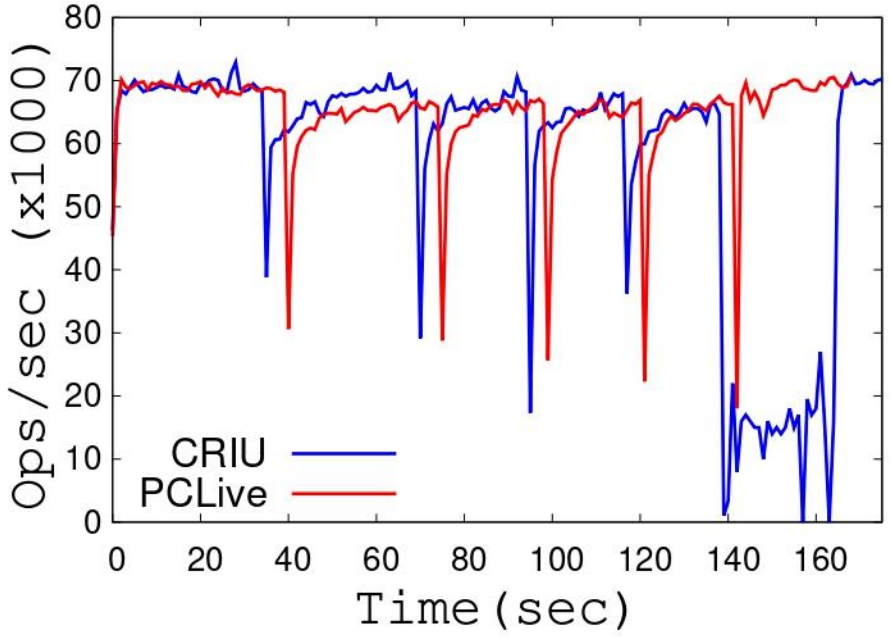

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- PCLive improves the application throughput during stop-and-copy phase.
- With PCLive, sometime throughput drop is slightly more during pre-dump iterations.

PCLive: Other Evaluations

- With high–speed network, PCLiveG performs better, e.g., 5.4x downtime improvement for 10Gbps.

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- PCLive is also evaluated with Benchbase (MySQL) and Graph500 workload.
- Please refer to the paper for more details.

Conclusion

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- PCLive addresses CPU and memory overhead with techniques such as PCLiveG and Delayed Restoration.
- With PCLiveG, the application container migration become similar to VM migration.

Thank You

Documentation and Source code:
https://www.github.com/shivbt/PCLive

Contact:
shivbt@cse.iitk.ac.in