UCLA Samueli School of Engineering

Canvas: Isolated and Adaptive Swapping for Multi-Applications on Remote Memory

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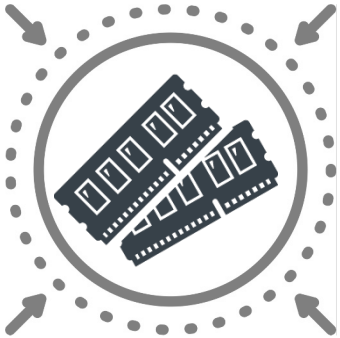
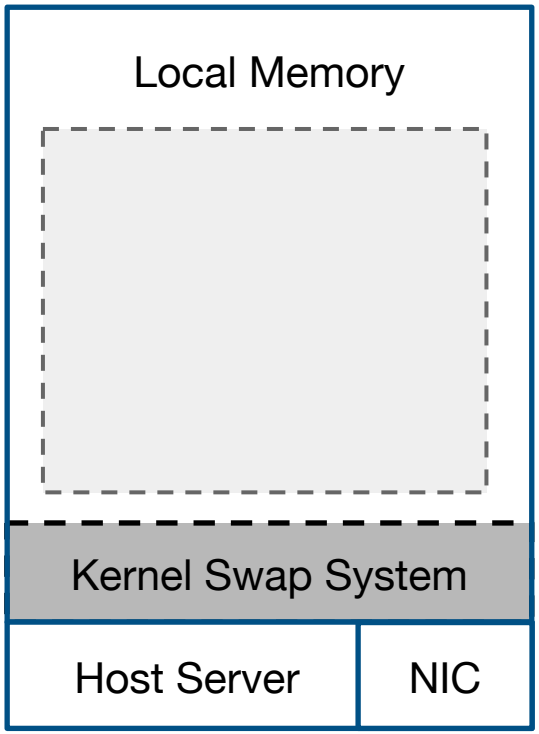
Memory Challenge in Datacenters



“Memory capacity wall”

Memory underutilization in datacenters

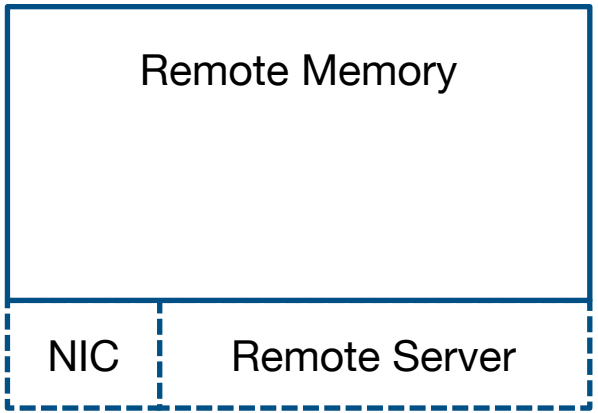
Remote Memory Systems



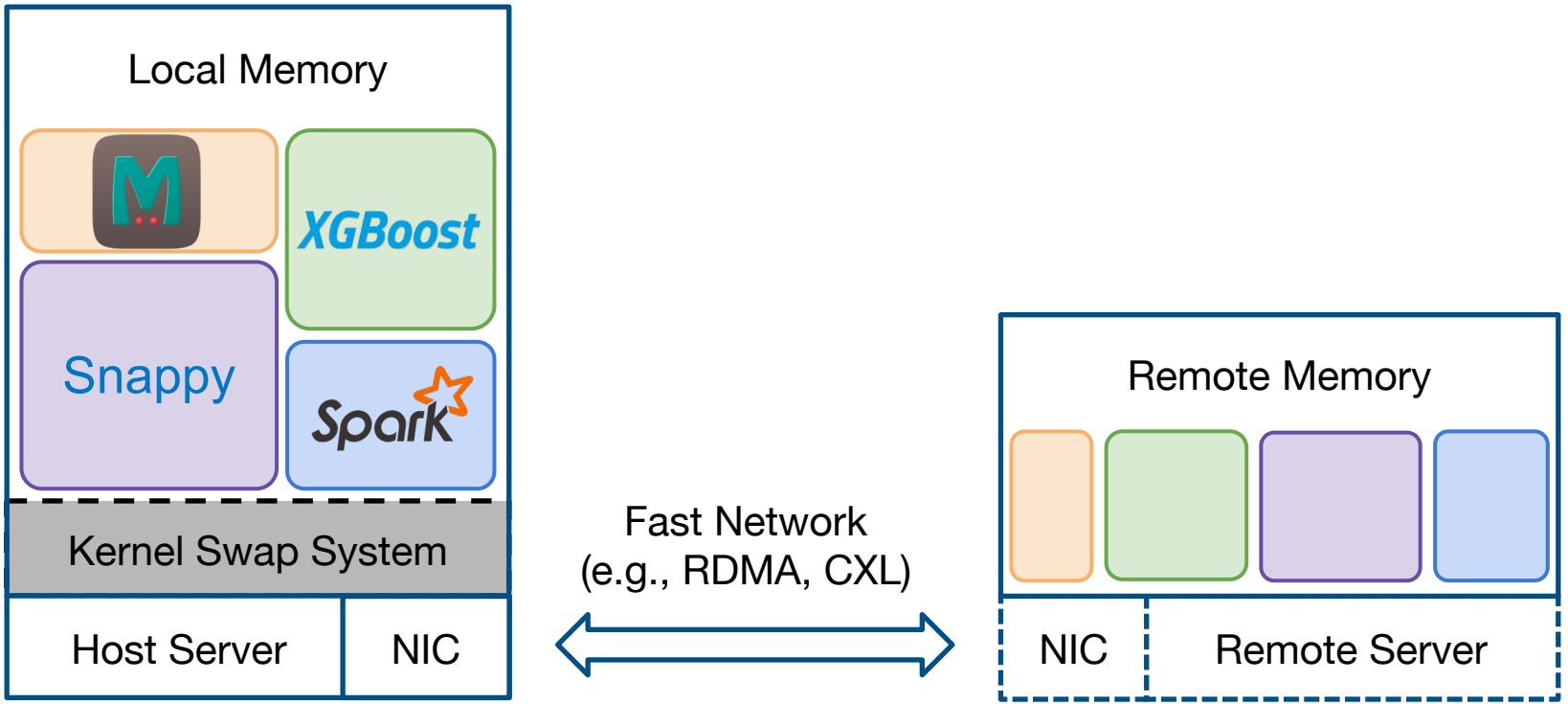
Efficiency: Fastswap [EuroSys'20], AIFM [OSDI'20]

Reliability: Hydra [Fast'22], Carbink [OSDI'22]

Multi-Tenancy ?



Multi-Tenant Cloud on Remote Memory



Kernel Swap Performs Poorly in Shared Settings

Experiment with four real-world cloud applications.

State of the art: Fastswap [EuroSys'20]

Google's file compression service

Memcached

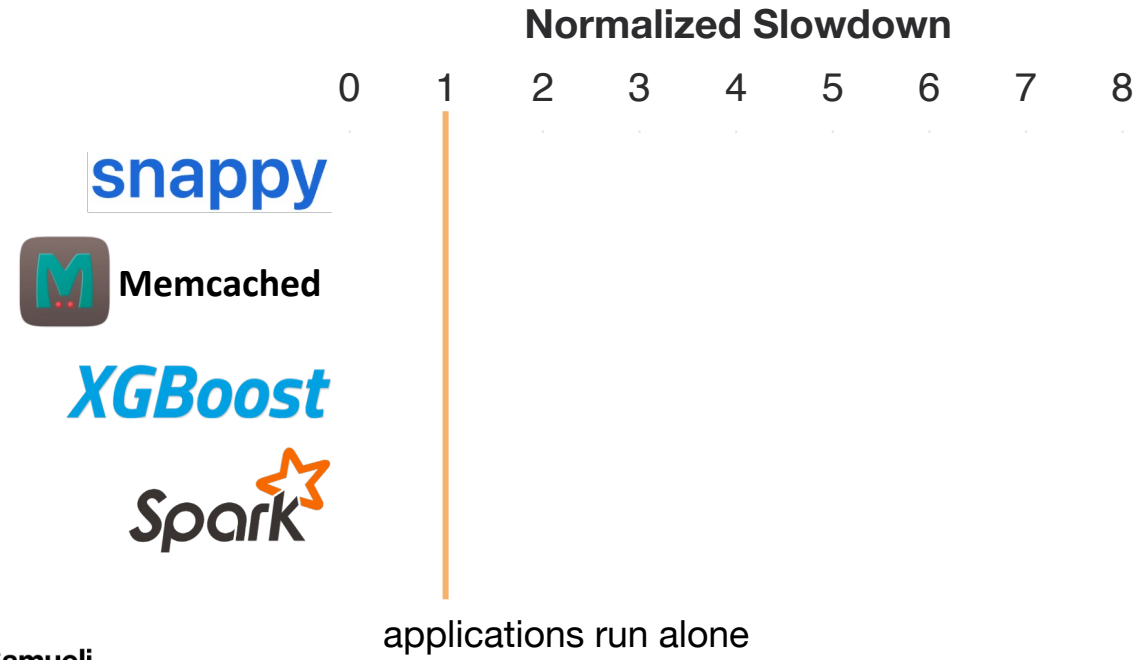
In memory key-value cache

CPU-based ML framework

Data-processing framework

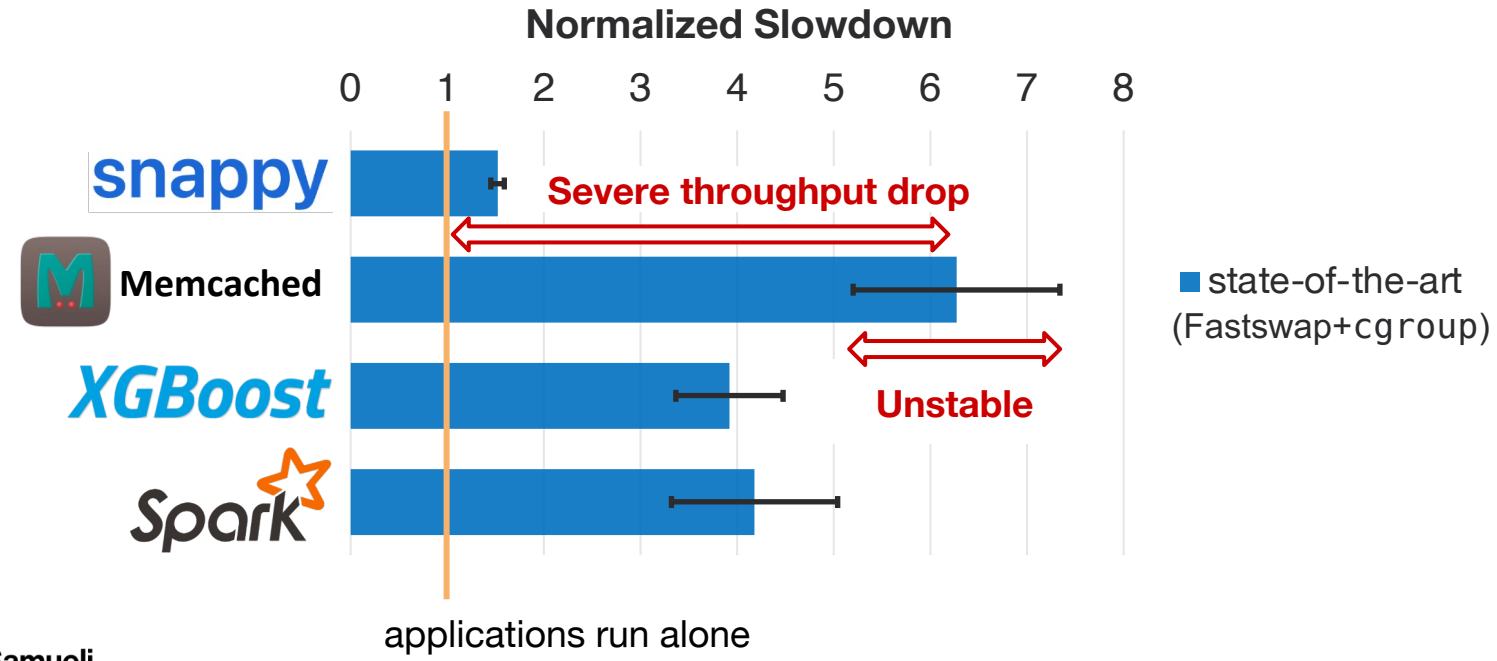
Kernel Swap Performs Poorly in Shared Settings

Run each application alone with 25% of their working sets cached in local memory.

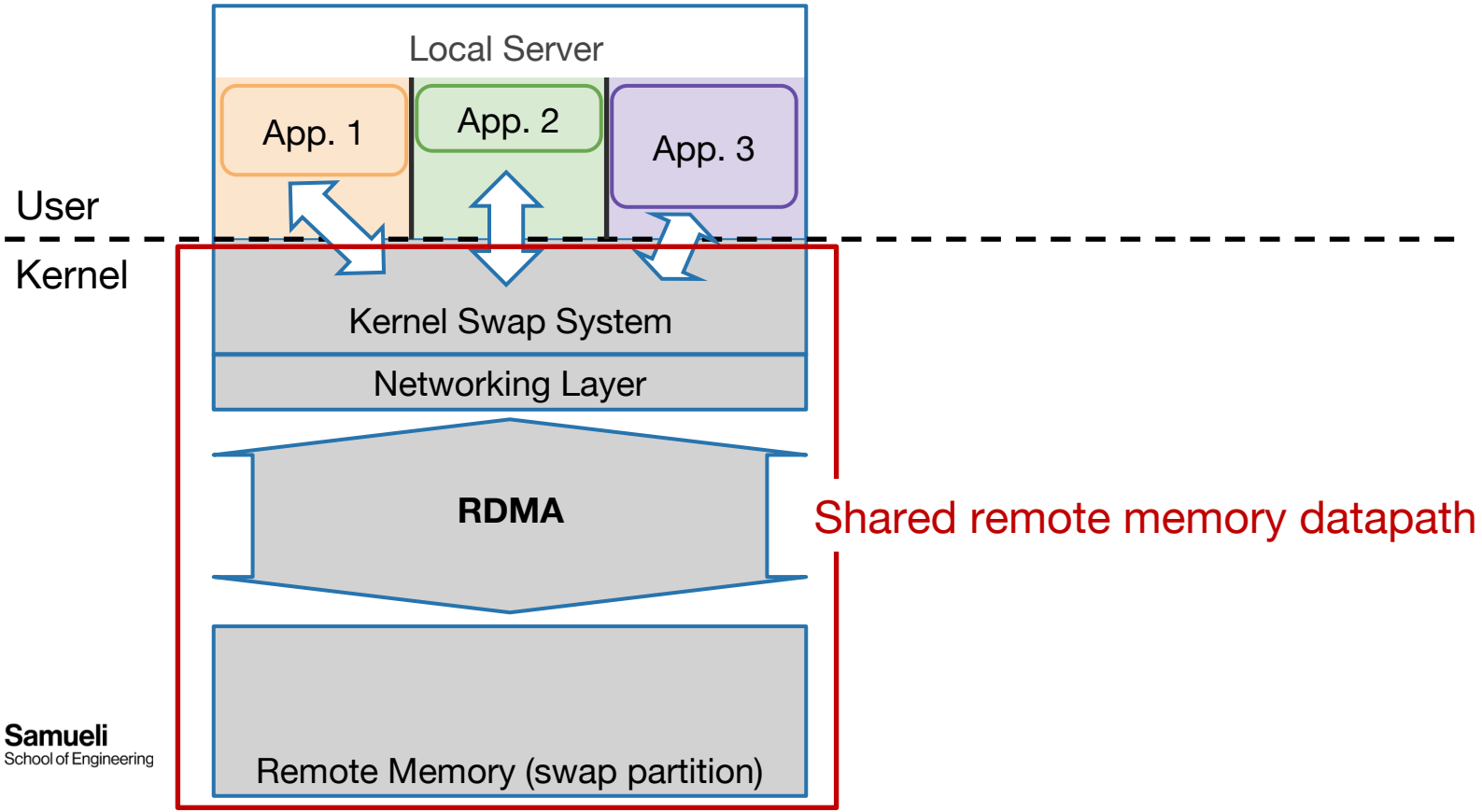


Kernel Swap Performs Poorly in Shared Settings

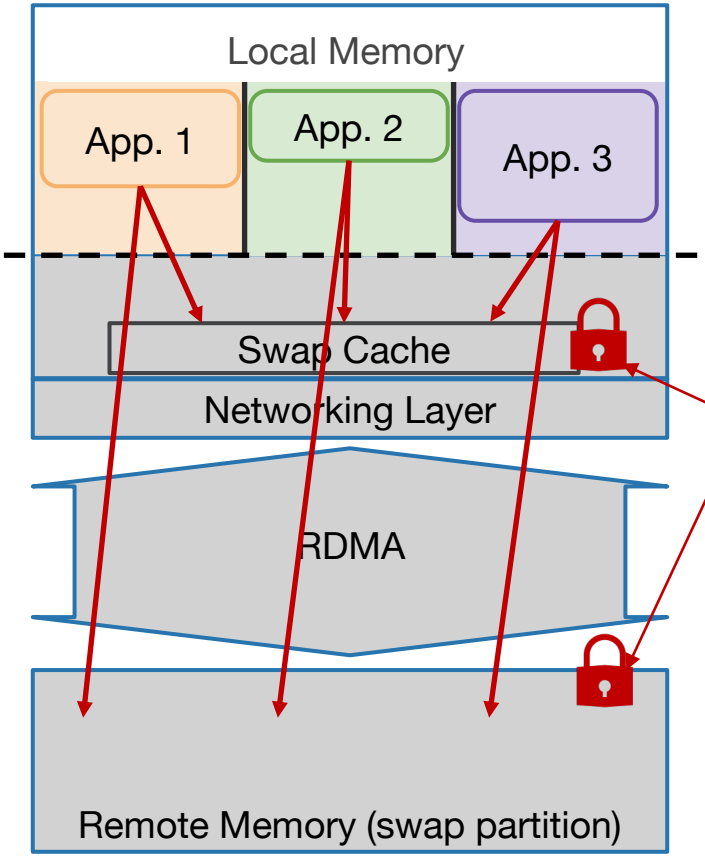
Co-run four real-world applications with 25% of their working sets cached in local memory.



Where Does The Overhead Come From?



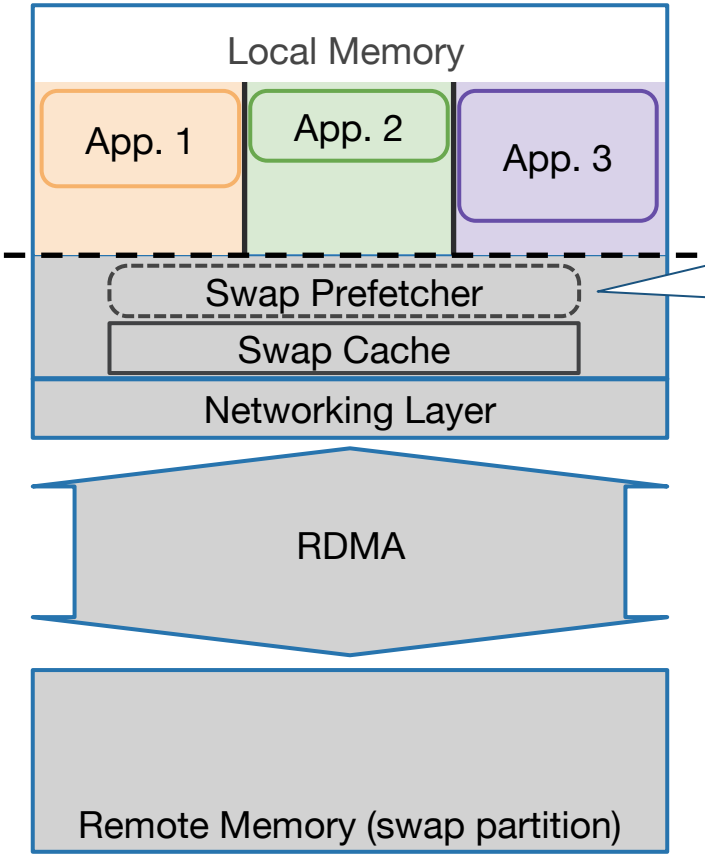
Interference #1: Shared Swap Resources

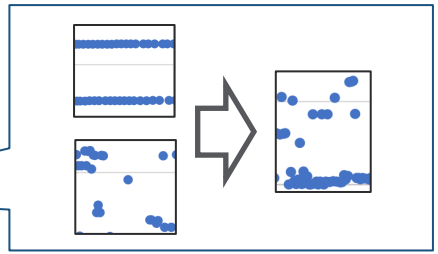


Lock contention when alloc./free

Swap throughput drops by *56%*

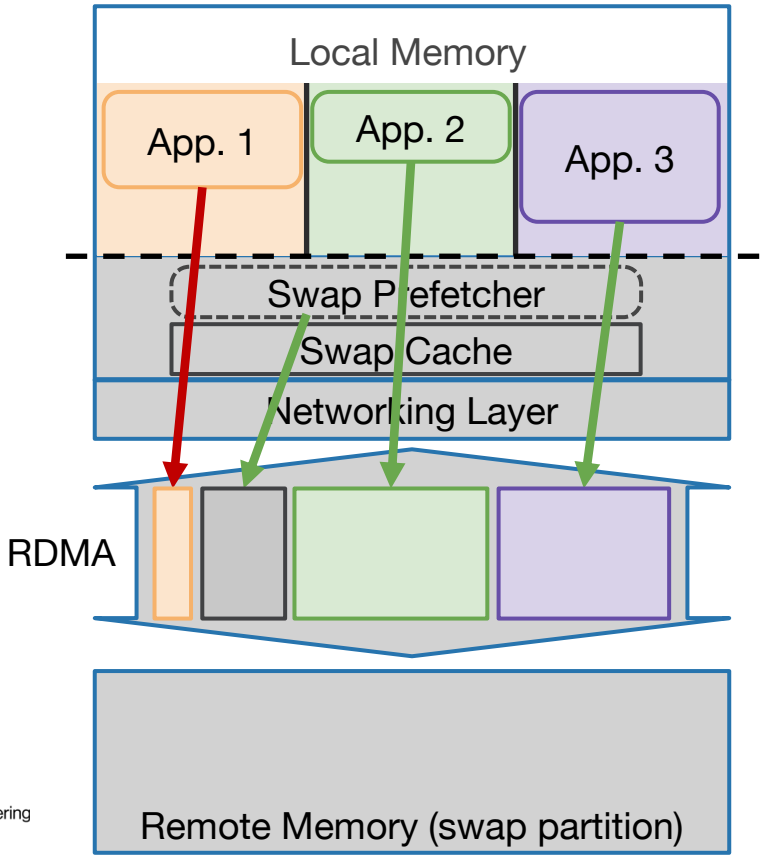
Interference #2: Mixed Access Patterns





Prefetch contribution drops by *33%*

Interference #3: RDMA Bandwidth Competition

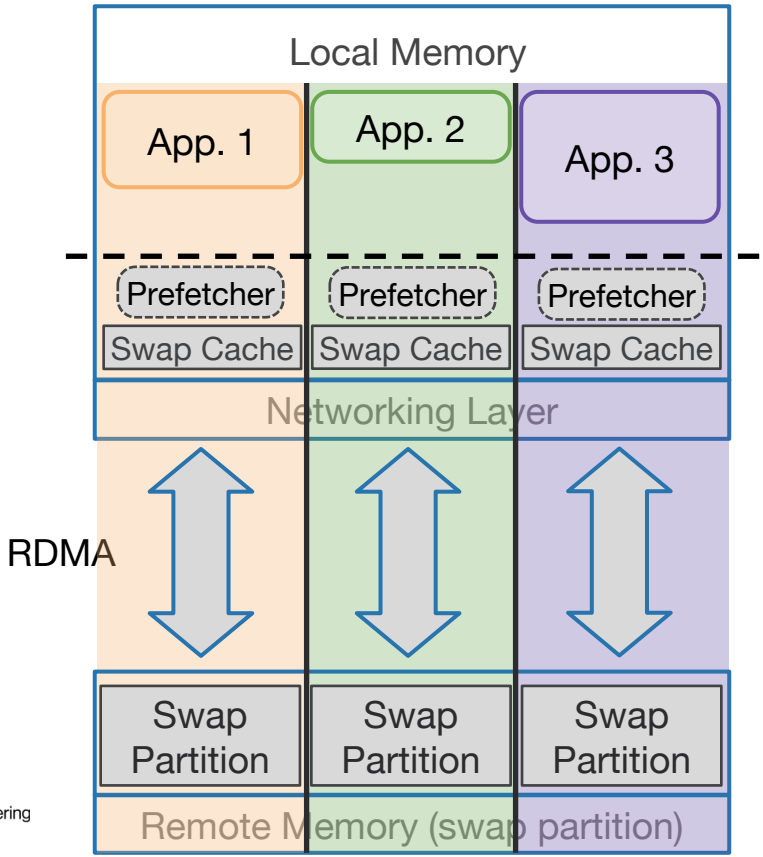


Competition occurs:

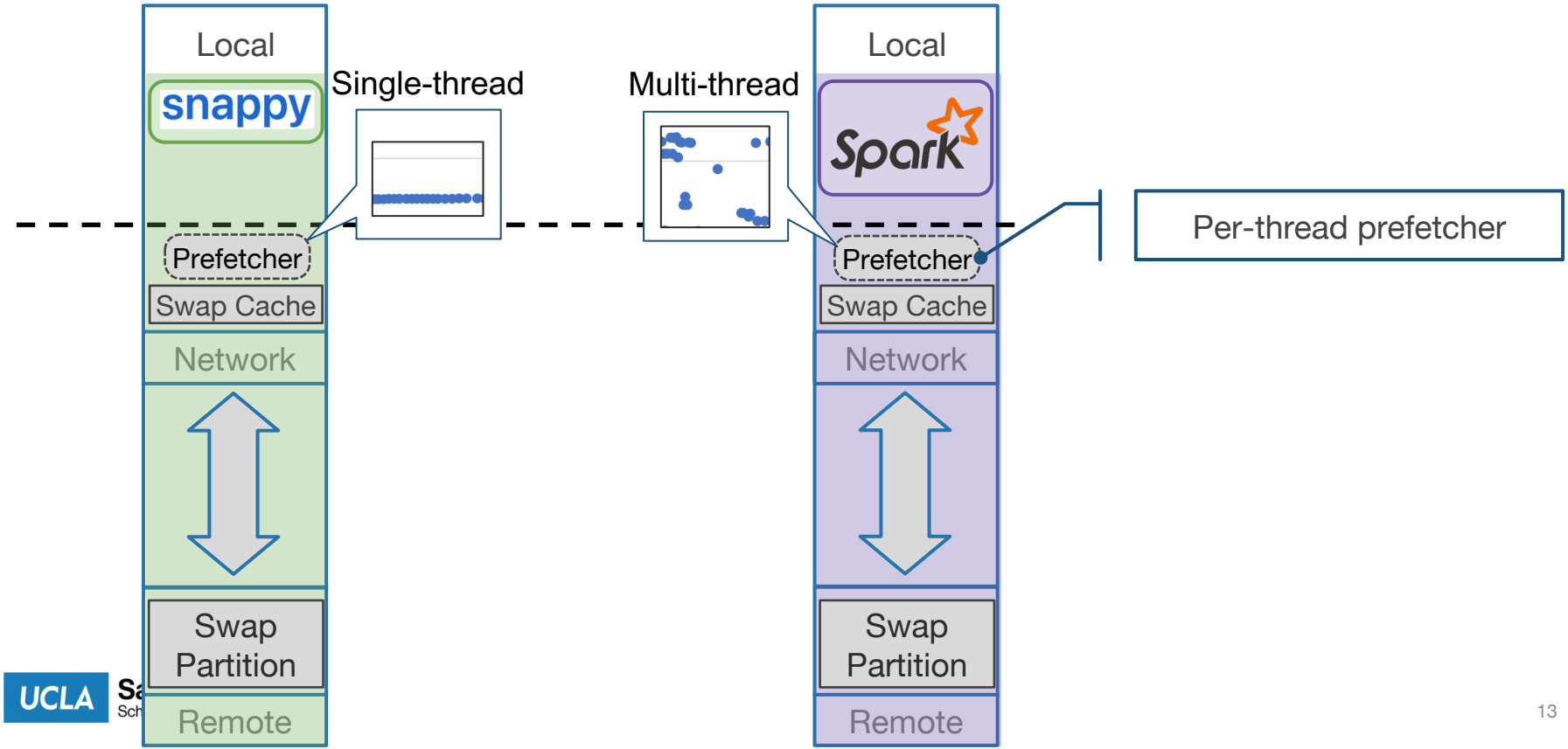
- among applications
- between application and prefetcher

P99 round-trip latency increases by *2.1x*

Canvas Design: Holistic Isolation



Isolation Enabled Adaptive Optimizations



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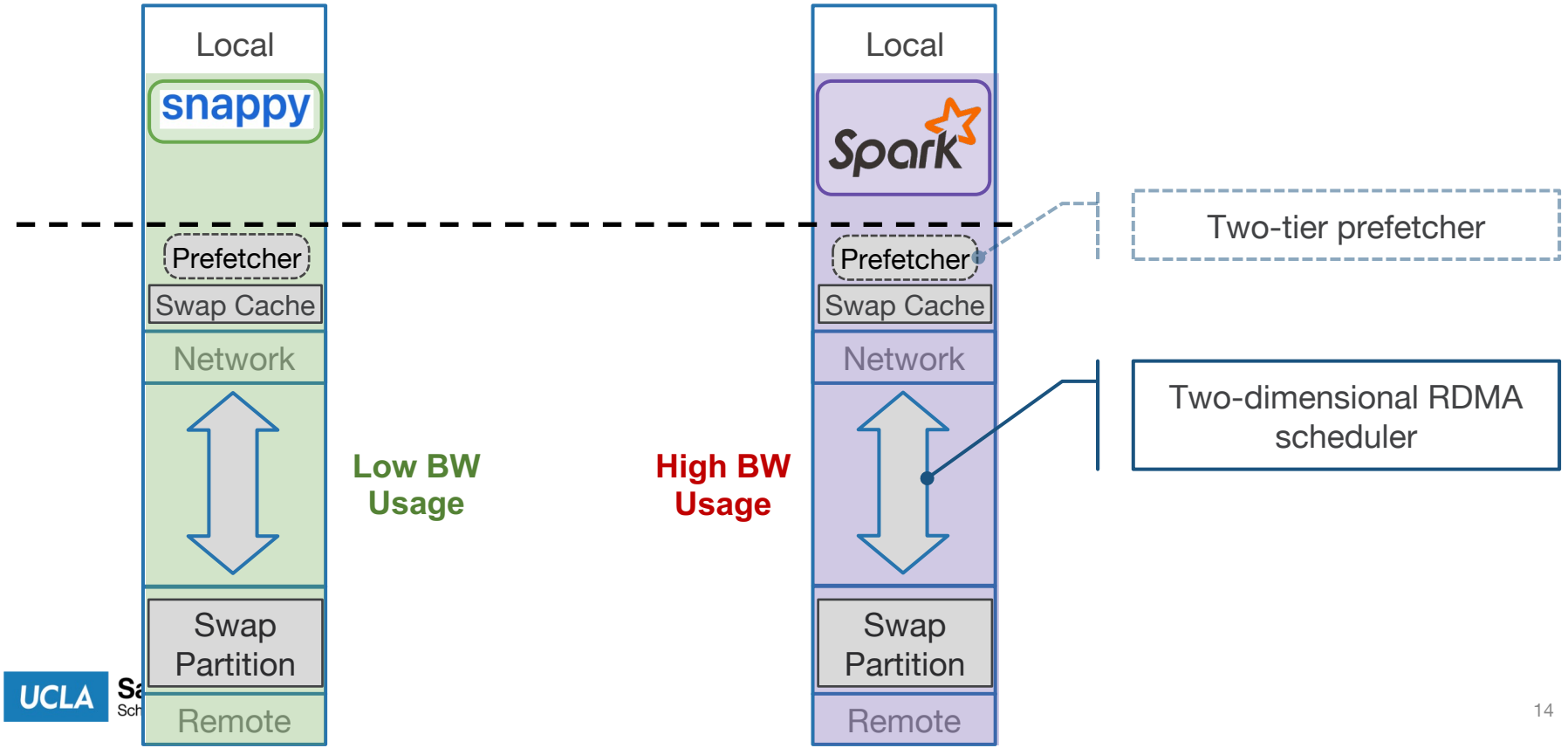
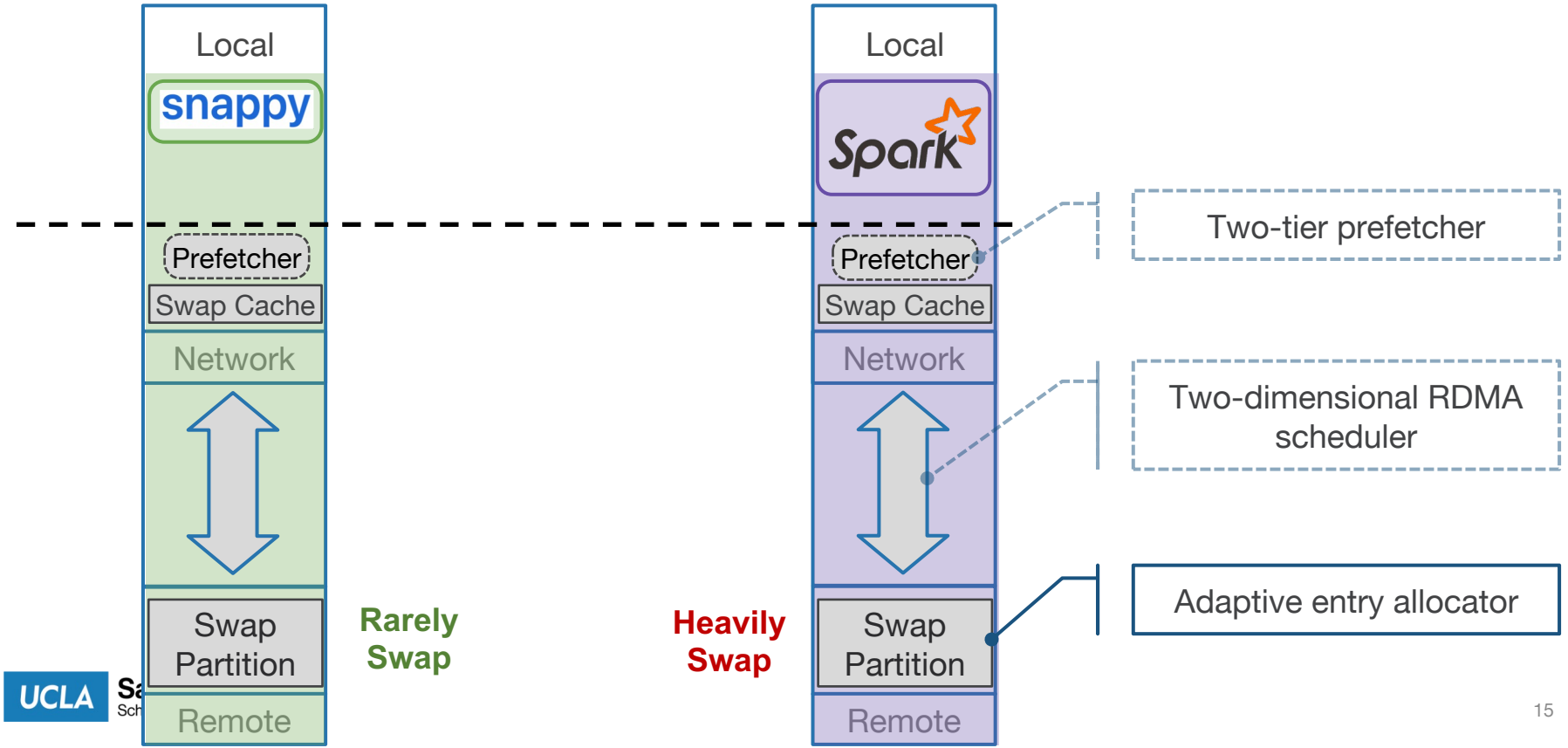
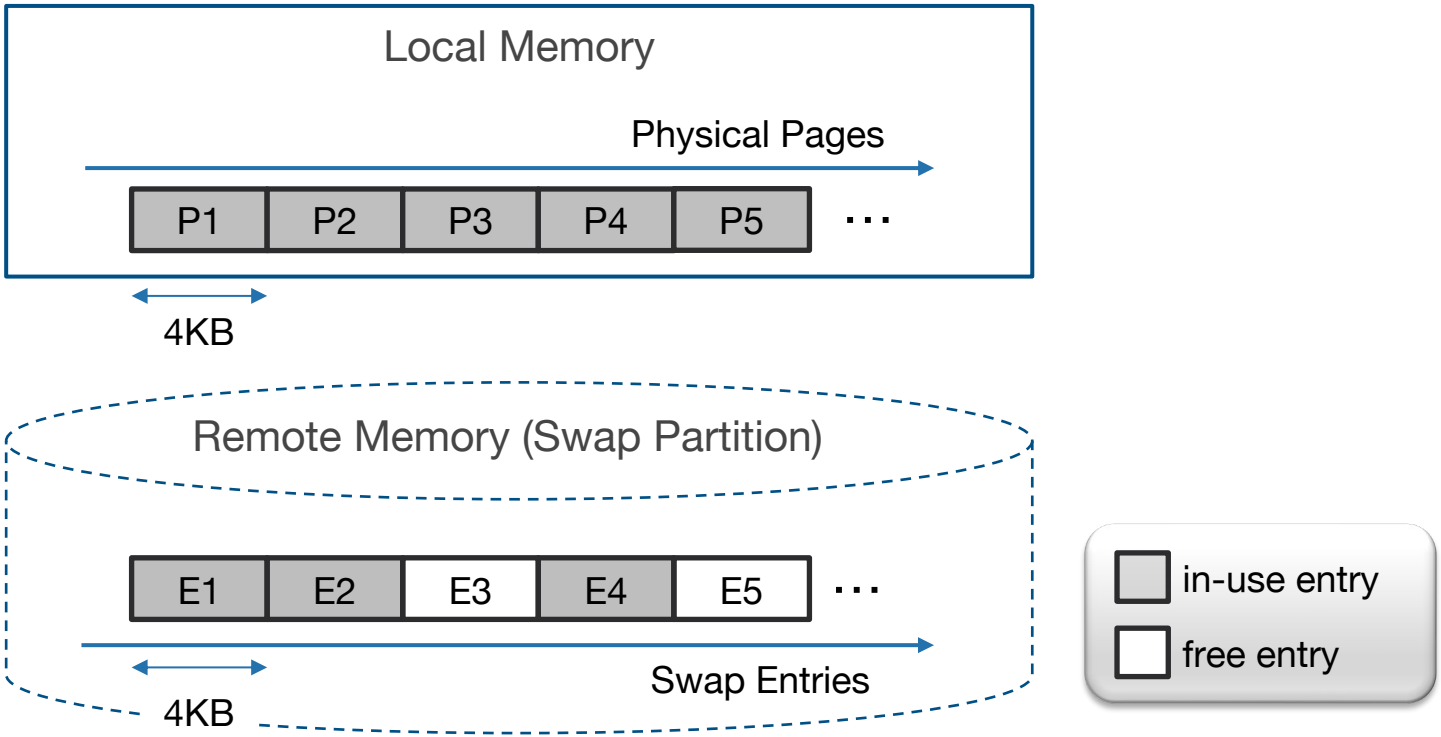


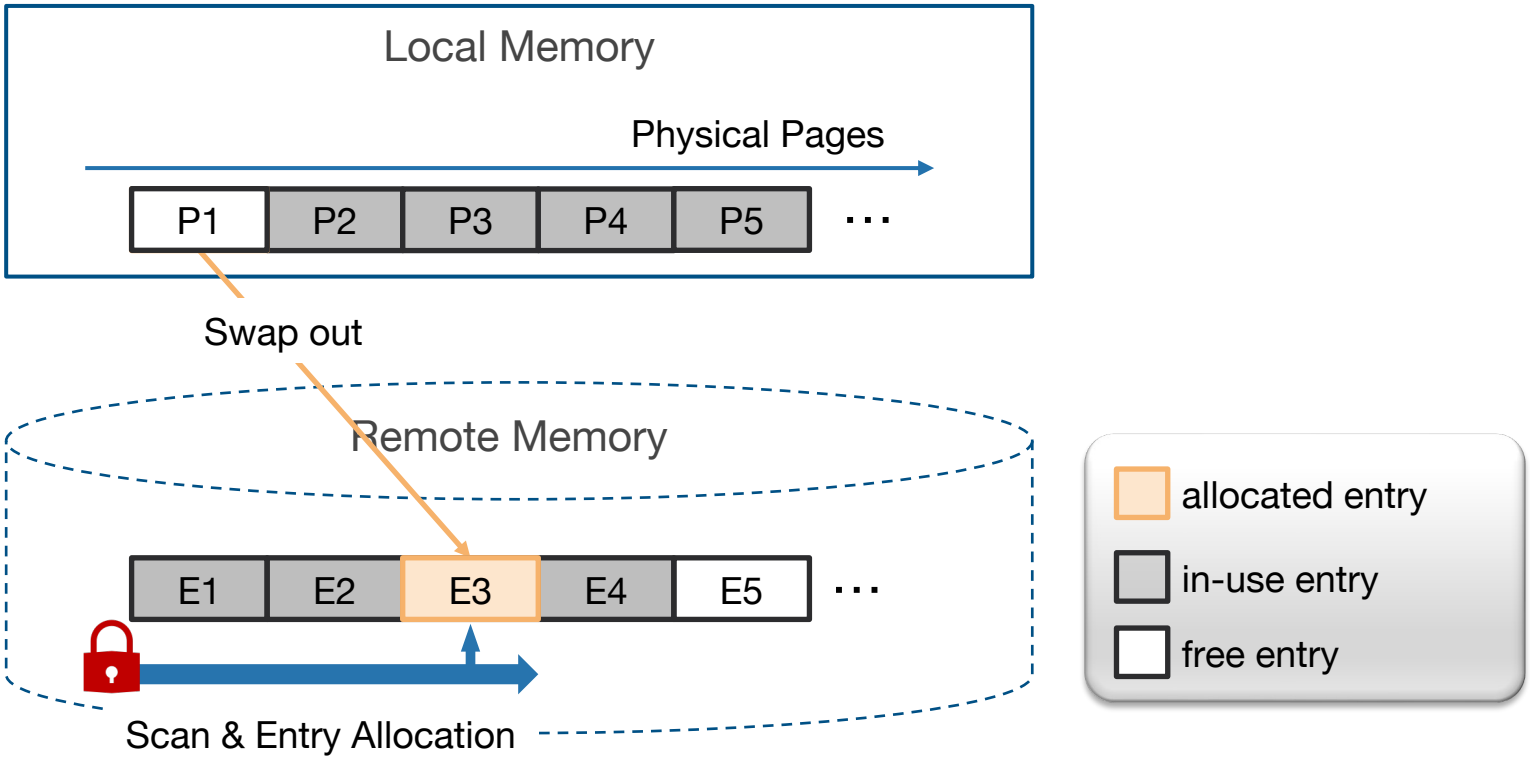
Isolation Enabled Adaptive Optimizations



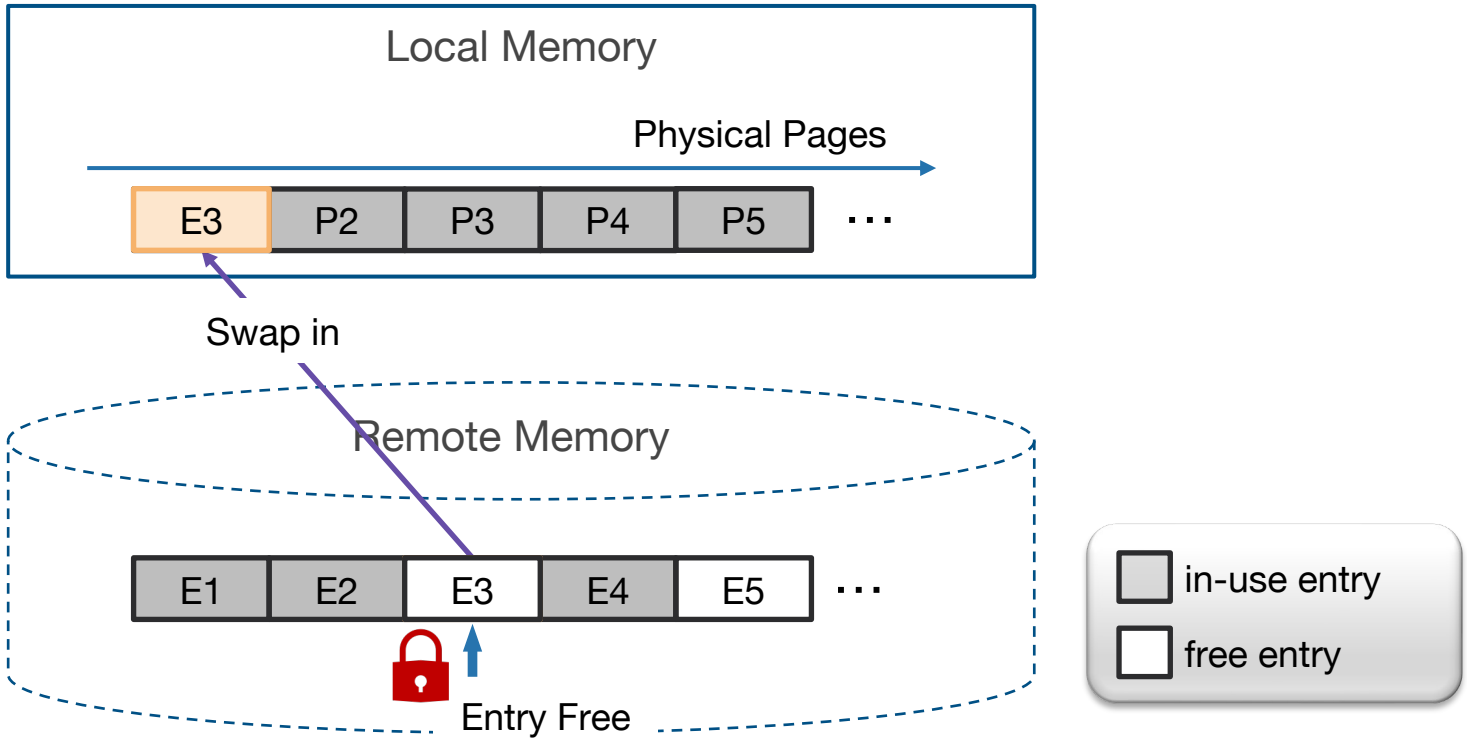
Remote Memory Management



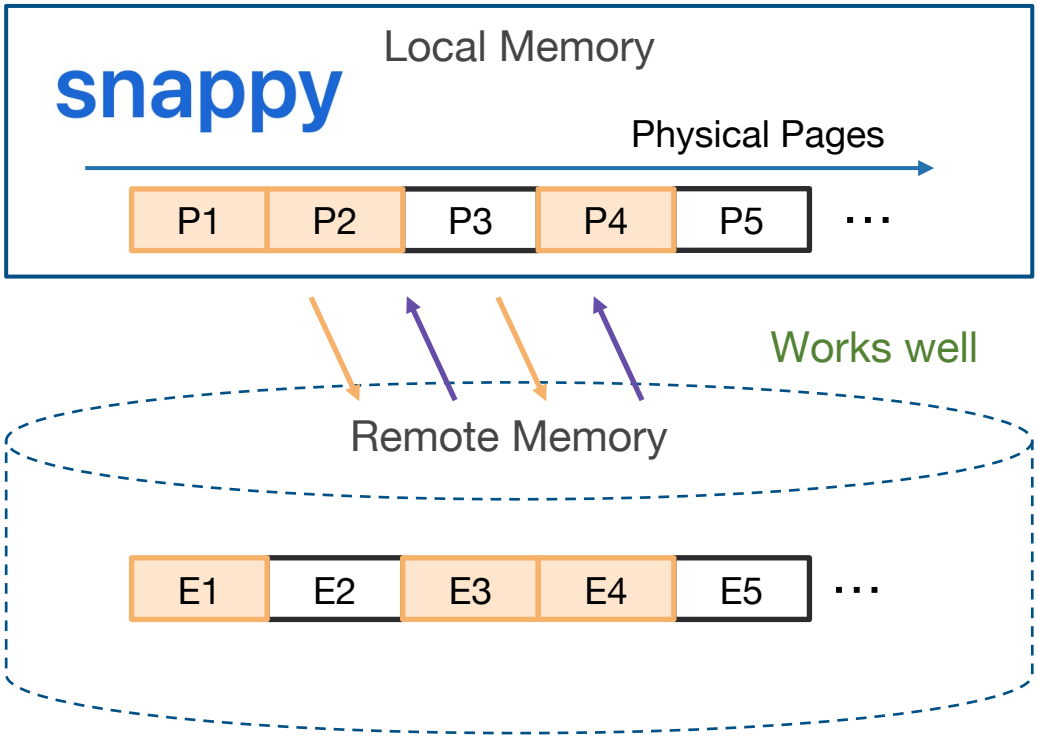
Remote Memory Management: Swap Out



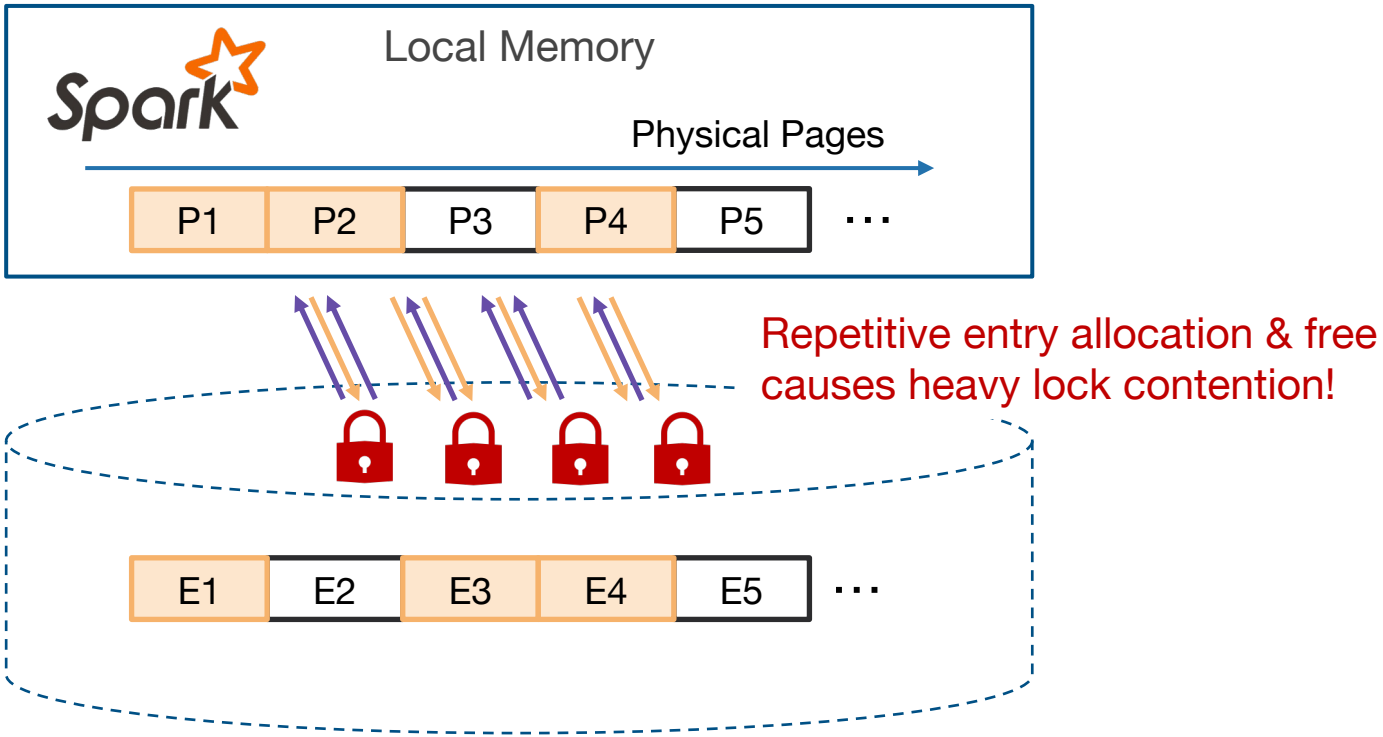
Remote Memory Management: Swap In



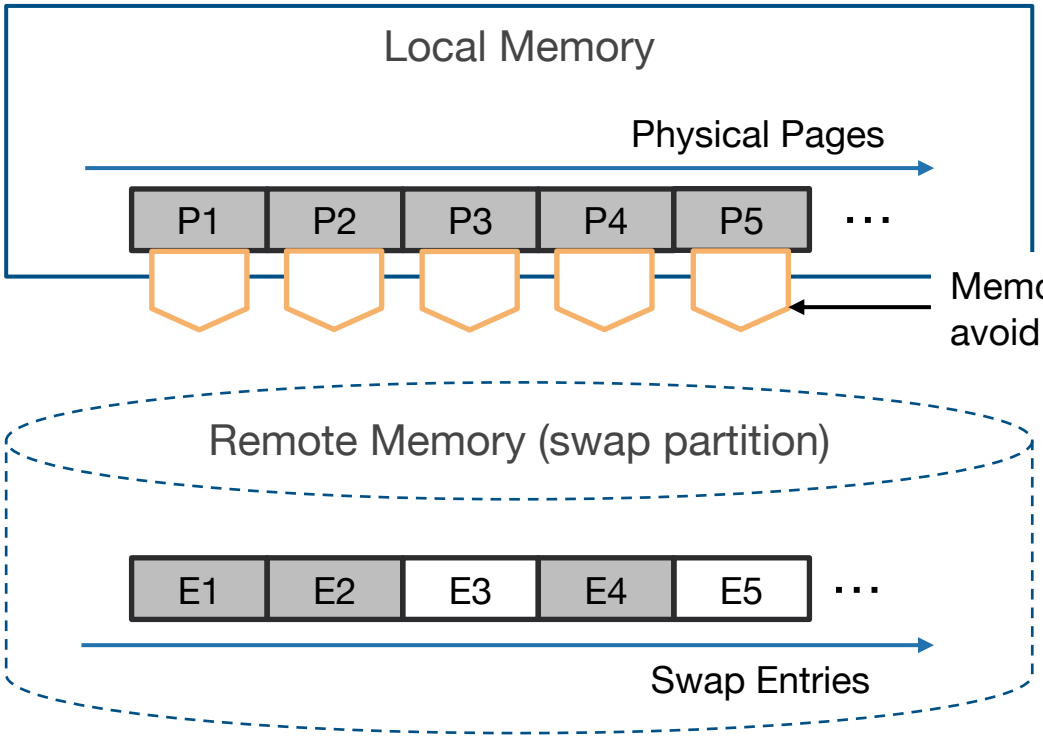
Efficient When Swap is Rare



Inefficient When Swap Is Intensive

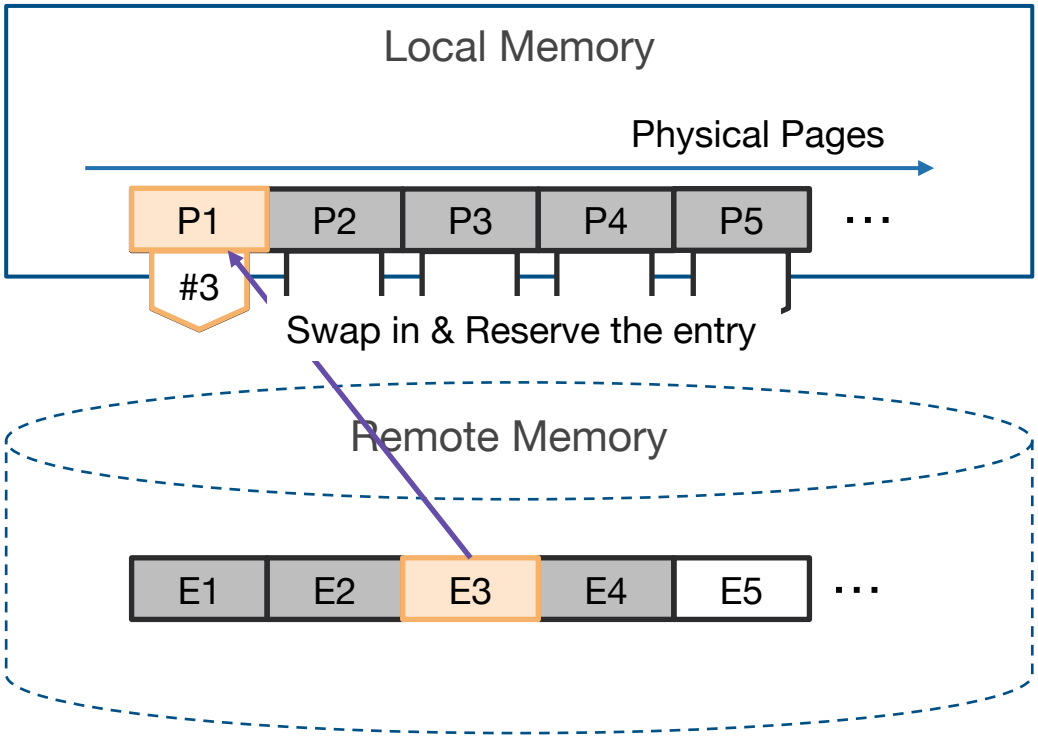


Adaptive Entry Allocator

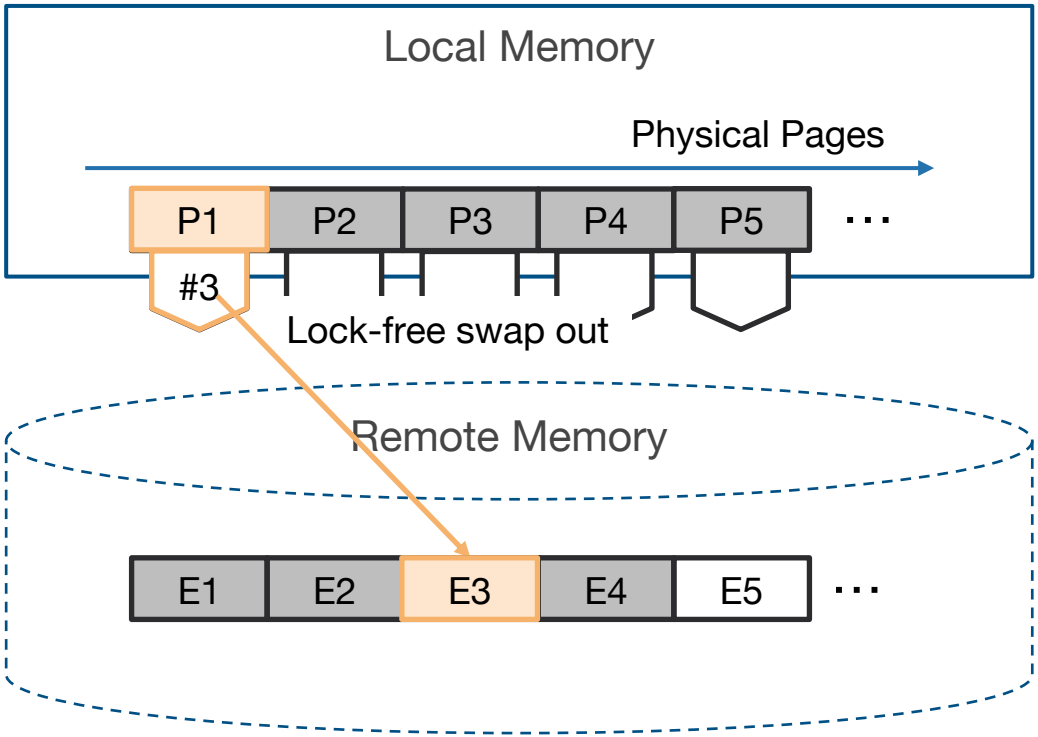


Sufficient remote memory:
Trade-off space for efficiency

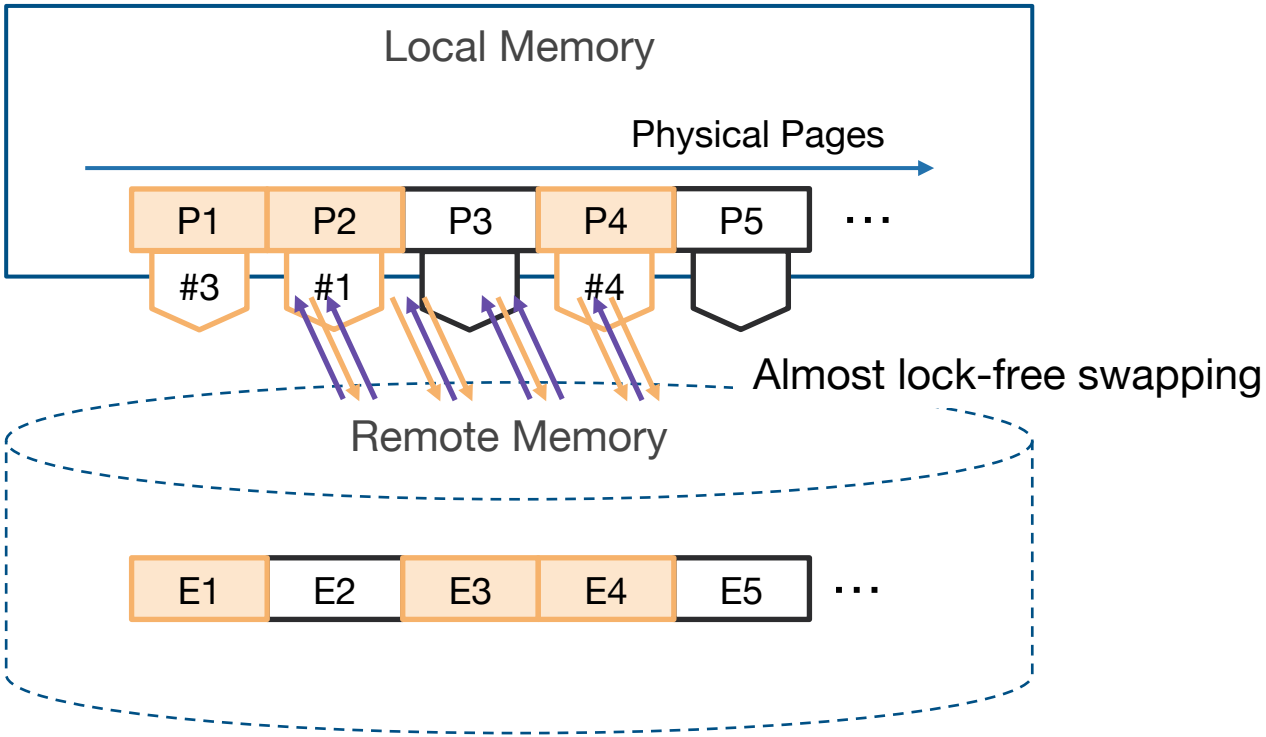
Adaptive Entry Allocator: Swap In & Reserve



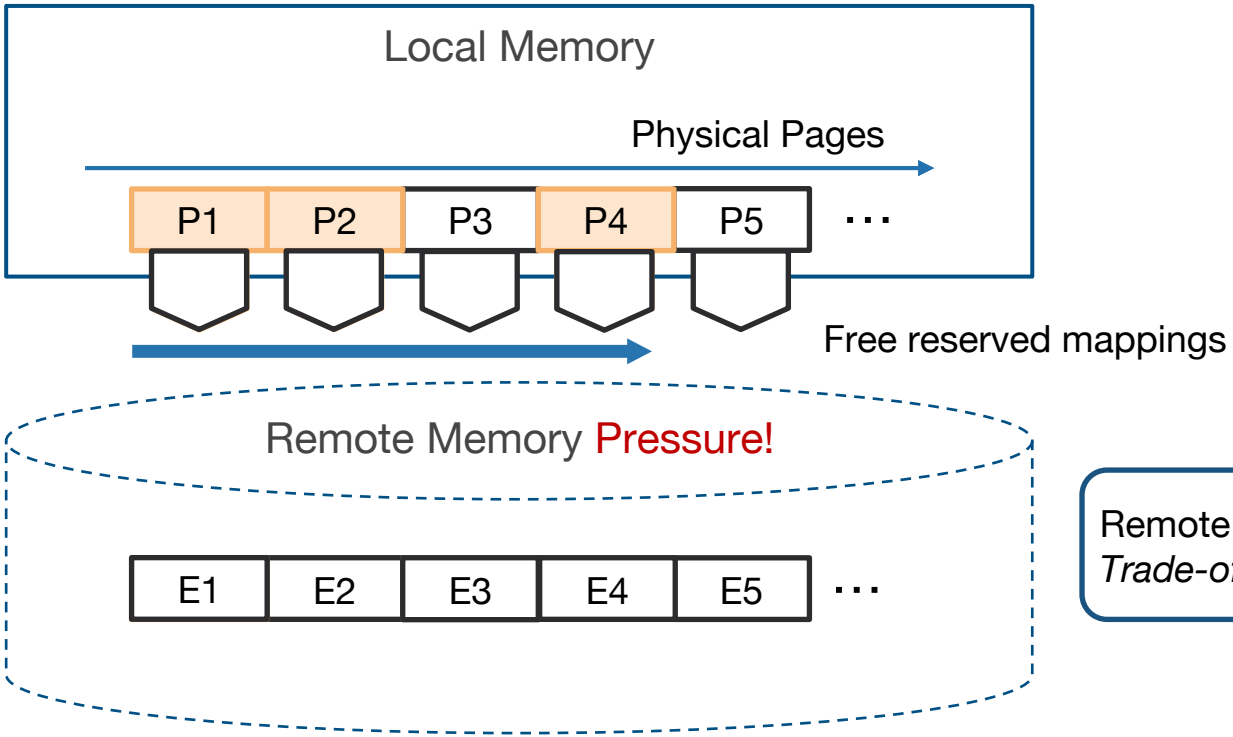
Adaptive Entry Allocator: Lock-Free Swap Out



Adaptive Entry Allocator: Intensive Swap



Adaptive Entry Allocator: Free Mappings



Remote memory pressure:
Trade-off time for space

Evaluation

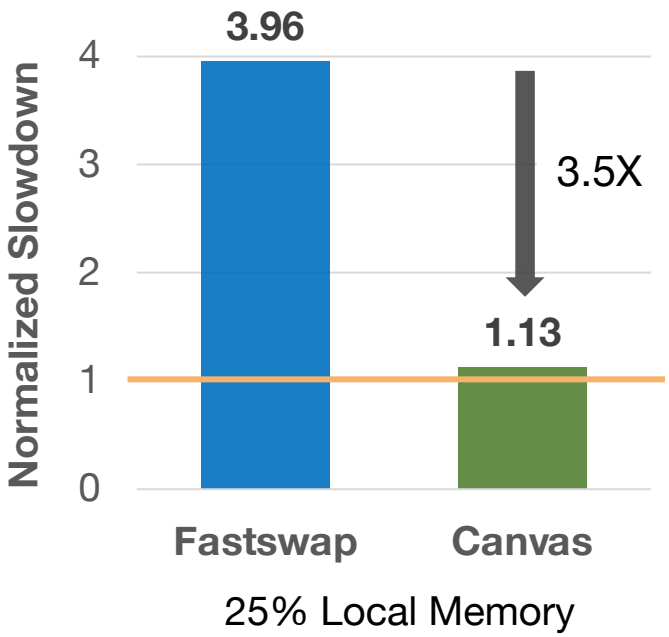
Evaluated on 6 real-world cloud applications with 11 workload combinations

State of the art: Linux `cgroup` on Fastswap [EuroSys'20]

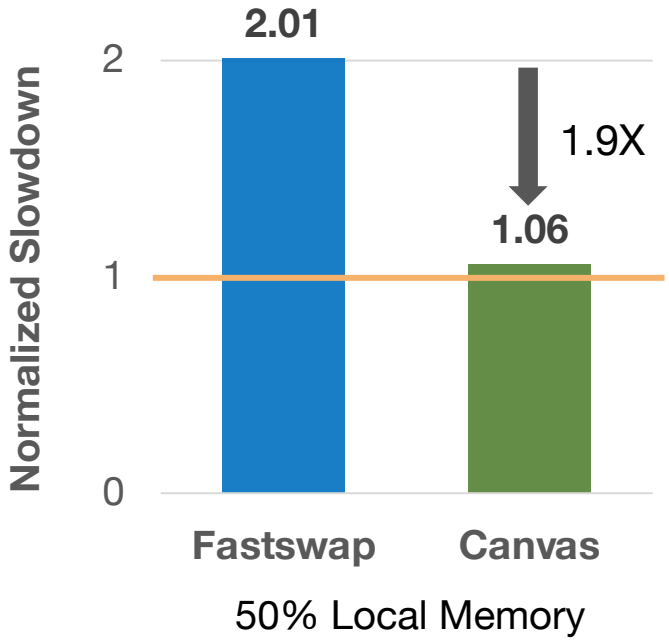
- How does Canvas improve throughput for co-running applications?
- How does Canvas reduce performance variation?

Results: Improved Throughput

Co-run Snappy, Memcached, XGBoost with Spark, Cassandra, and Neo4j, respectively



25% Local Memory

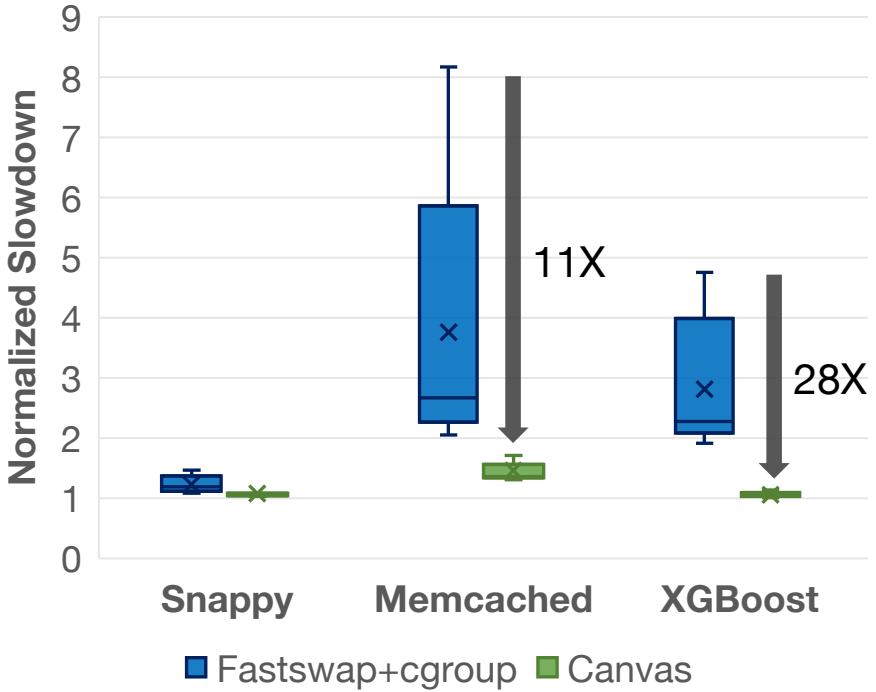


50% Local Memory

Results: Reduced Performance Variation

Fix Snappy, Memcached, and XGBoost and co-run them with another Java application

- 11 workload combinations in total
- Under 25% local memory
- On average 7.4x variation reduction



Conclusion

Canvas: holistic isolation + adaptive optimizations

- Isolation is necessary for real deployment of remote memory
- Isolation improves performance and QoS for shared remote memory
- Isolation enables adaptive optimizations for further performance boosts

- Canvas offers co-running applications 6.2x speedup and 7.4x variation improvement

https://github.com/uclasystem/canvas

Thank You!