Kingsguard: Write-Rationing Garbage Collection for Hybrid Memories

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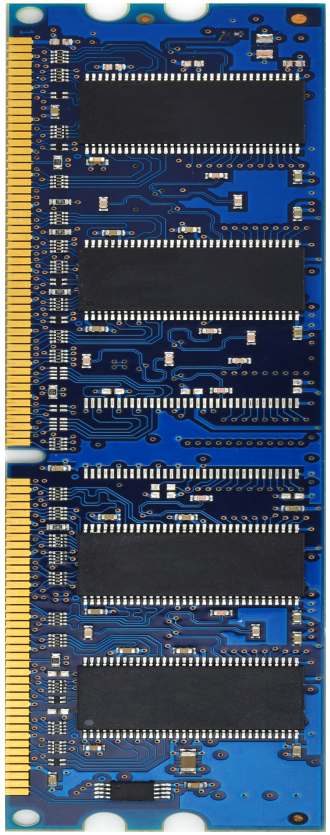
DRAM is facing challenges

Scalability

Reliability

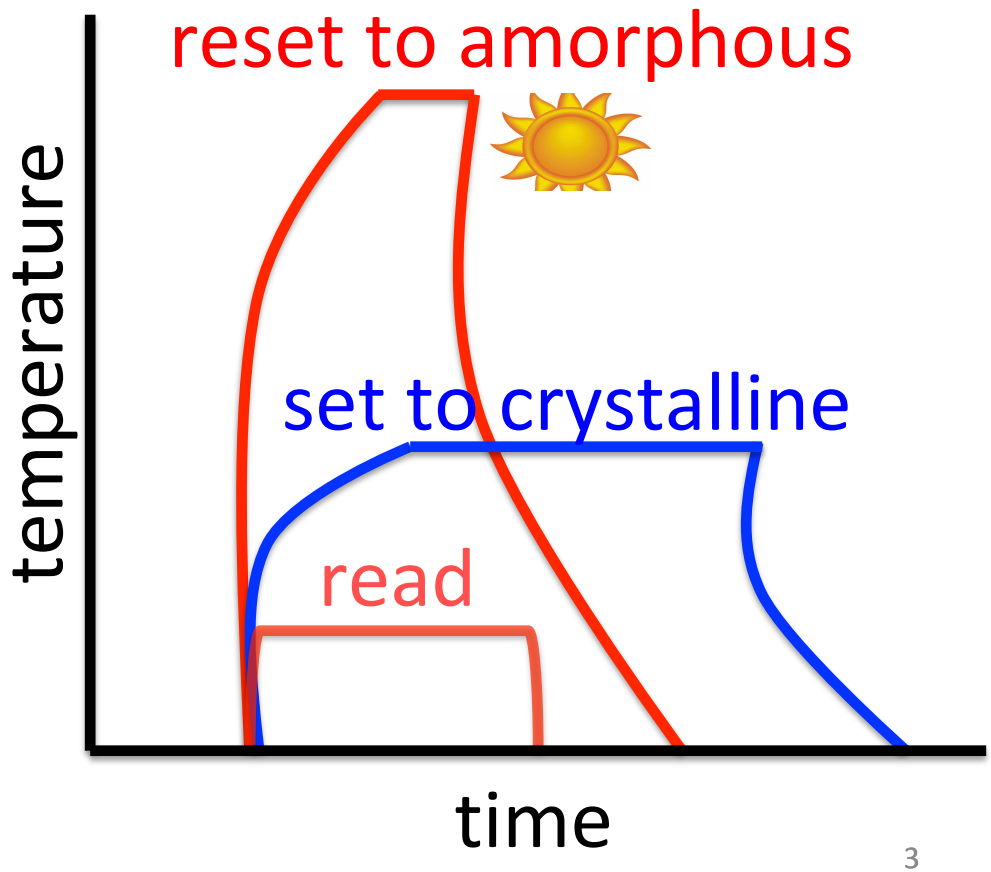
Energy



Phase change memory is promising

But …

- GB/$ ☺
- Latency ☹
- Endurance ☹



Hybrid DRAM-PCM memory

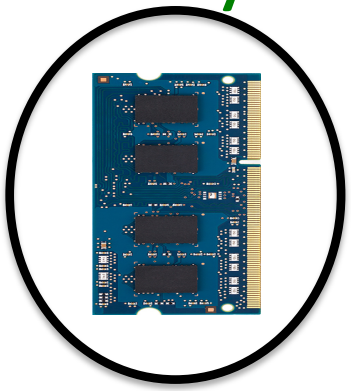
DRAM	PCM
Speed Endurance	Energy Capacity

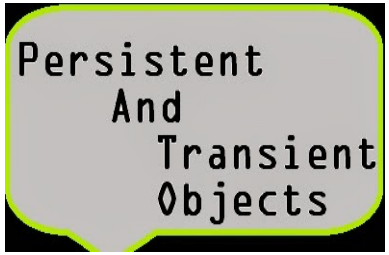
Challenge

Mitigate PCM wear-out and extend its lifetime

How to mitigate PCM wear-out?

Phase change memory as …





Wear Level

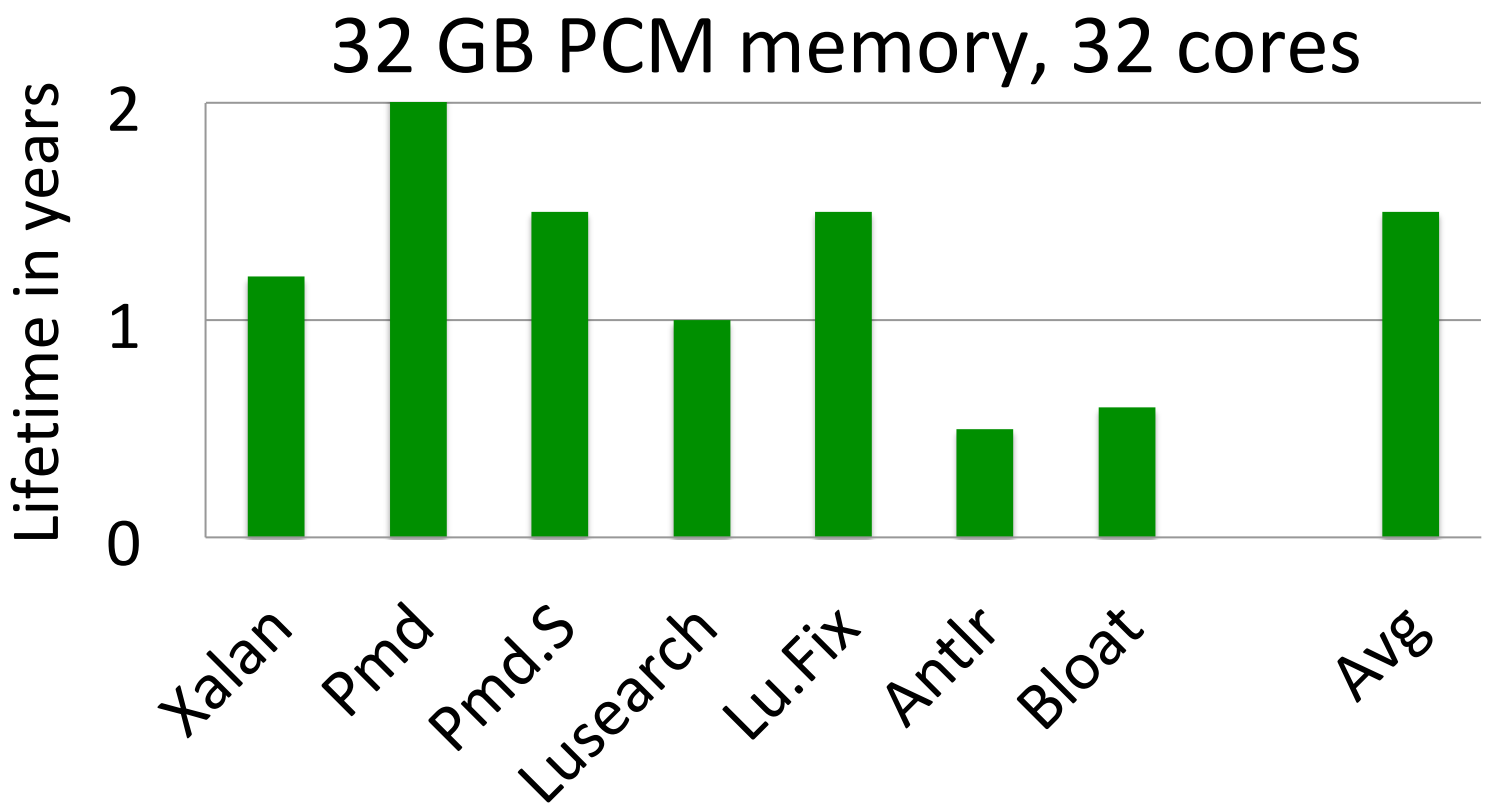
Wear Level

Wear Level

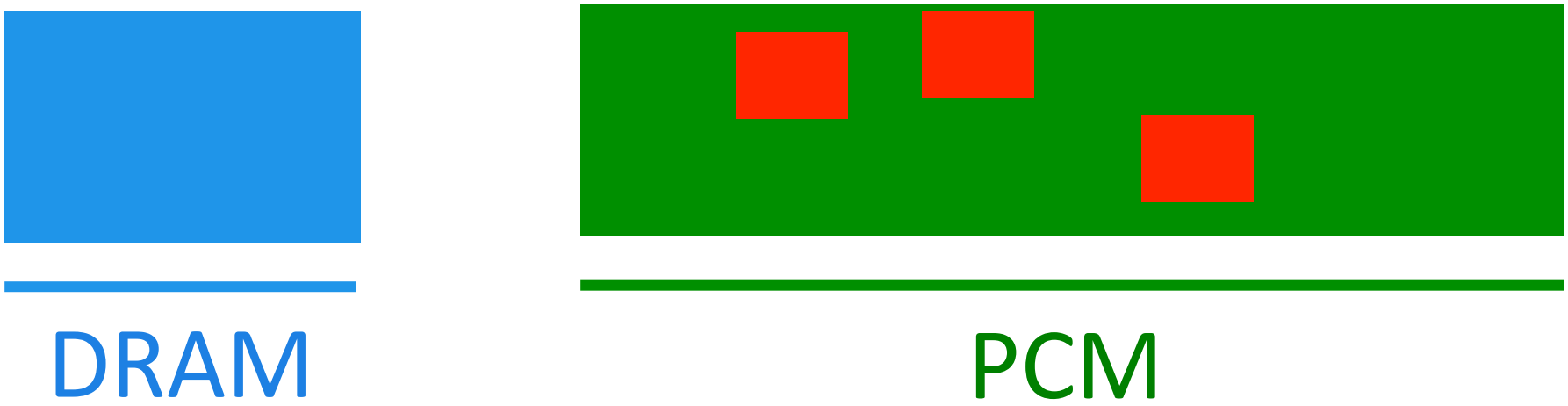
Operating System

Language runtime

PCM only with leveling is not practical



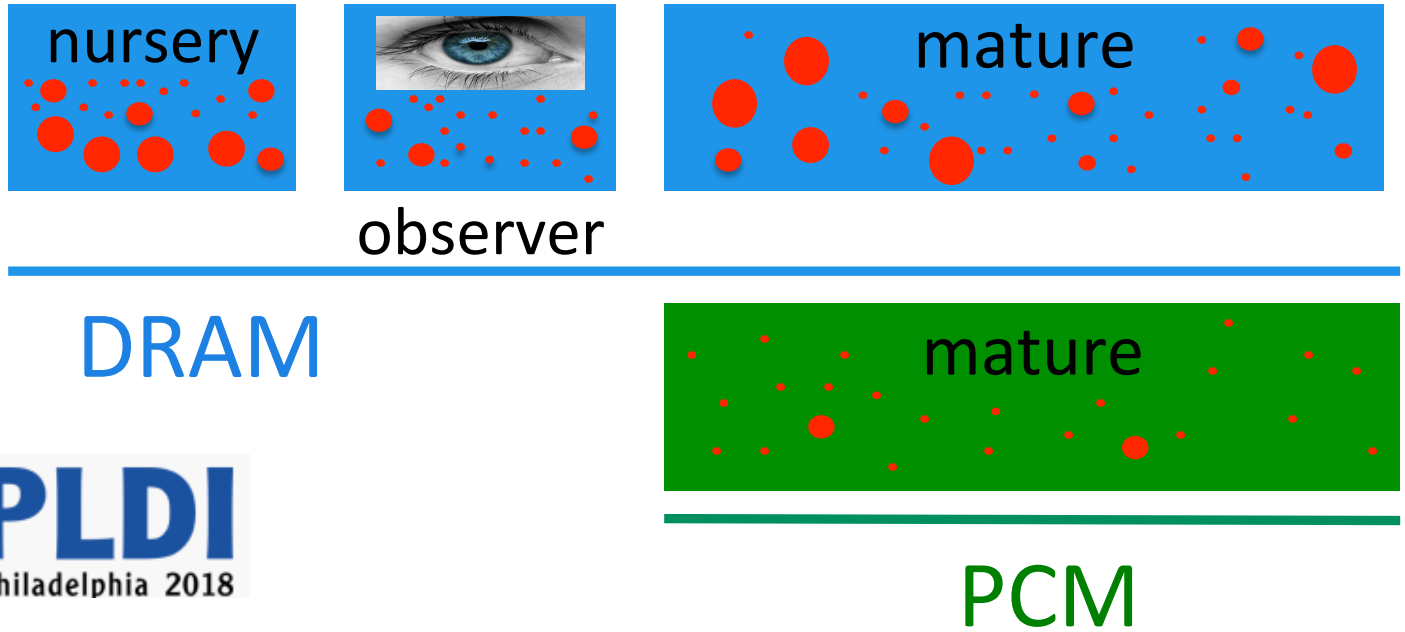
OS to limit PCM writes



Drawbacks

- Coarse grained
- Page migrations can be costly

Managed runtime to limit PCM writes



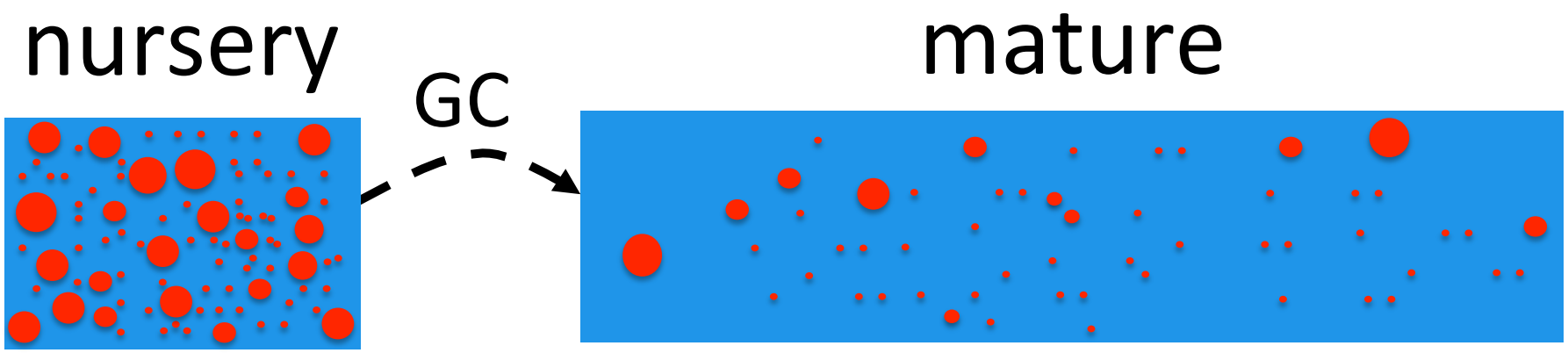
Our work uses garbage collection to keep highly written objects in DRAM

Distribution of writes in GC runtime

70%

of writes

Distribution of writes in GC runtime



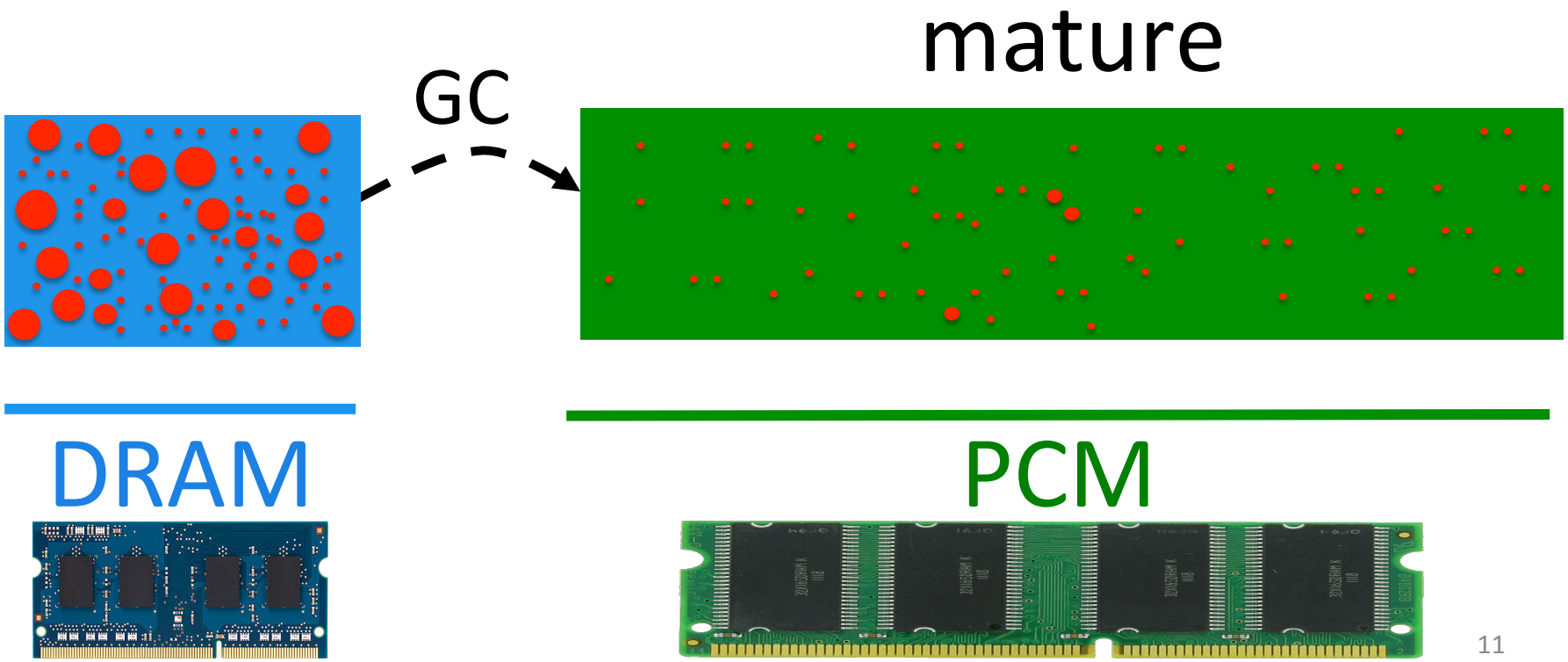
70%

of writes

22%

to 2% of objects

Contribution
Write-Rationing Garbage Collectors

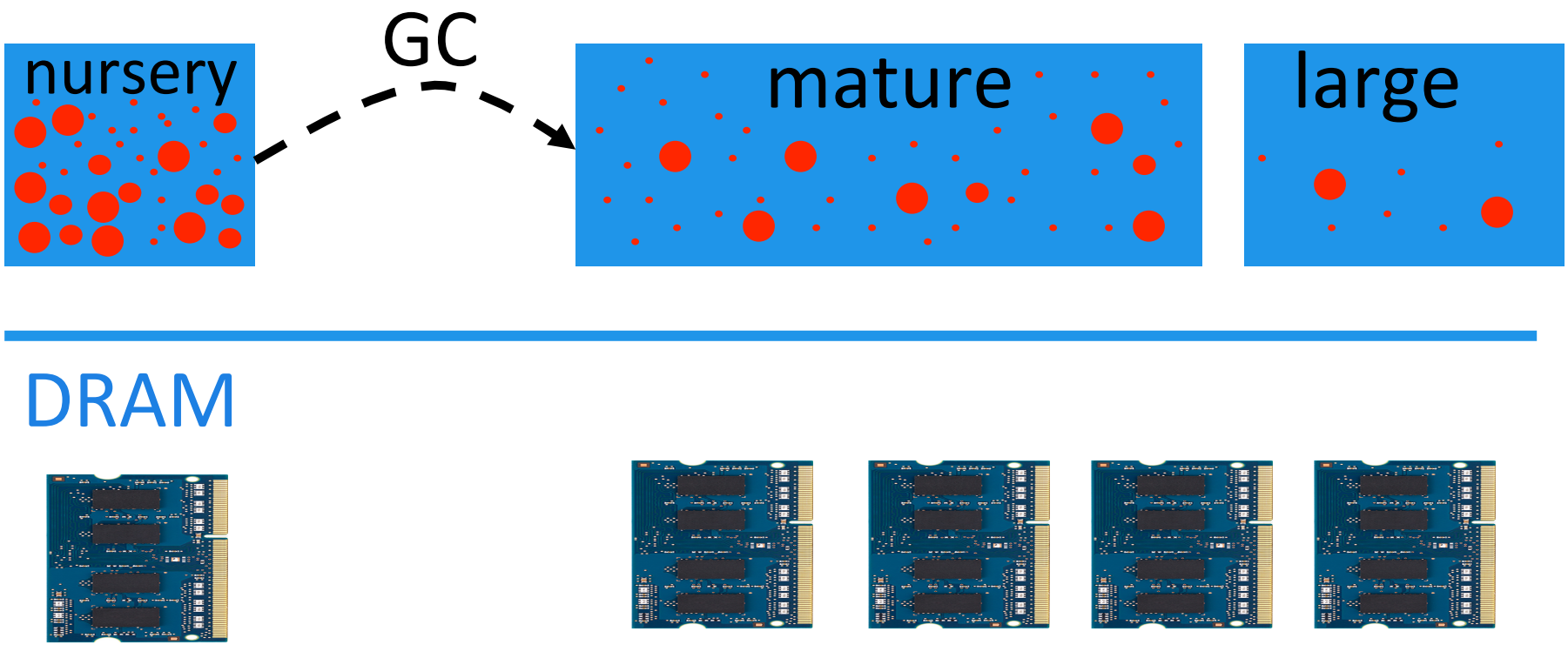


Two write-rationing garbage collectors

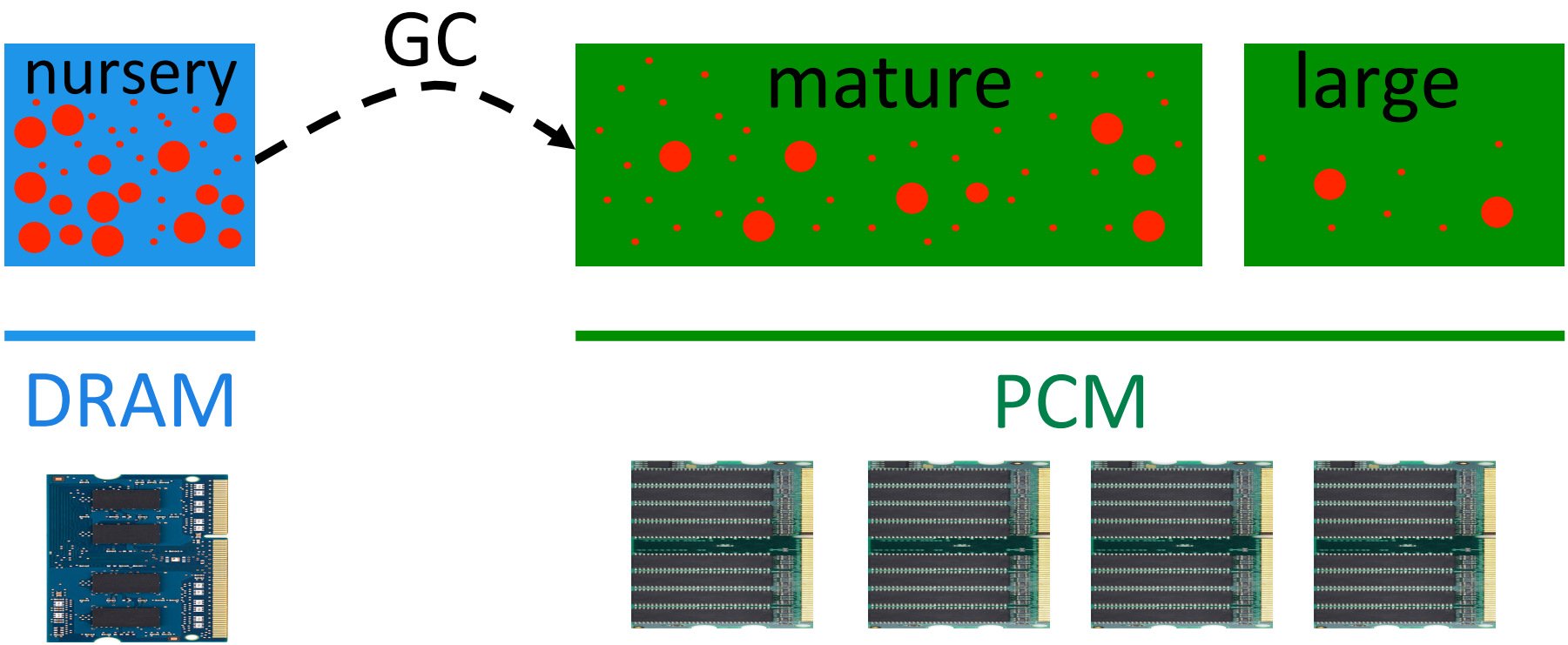
Kingsguard-Nursery

Kingsguard-Writers

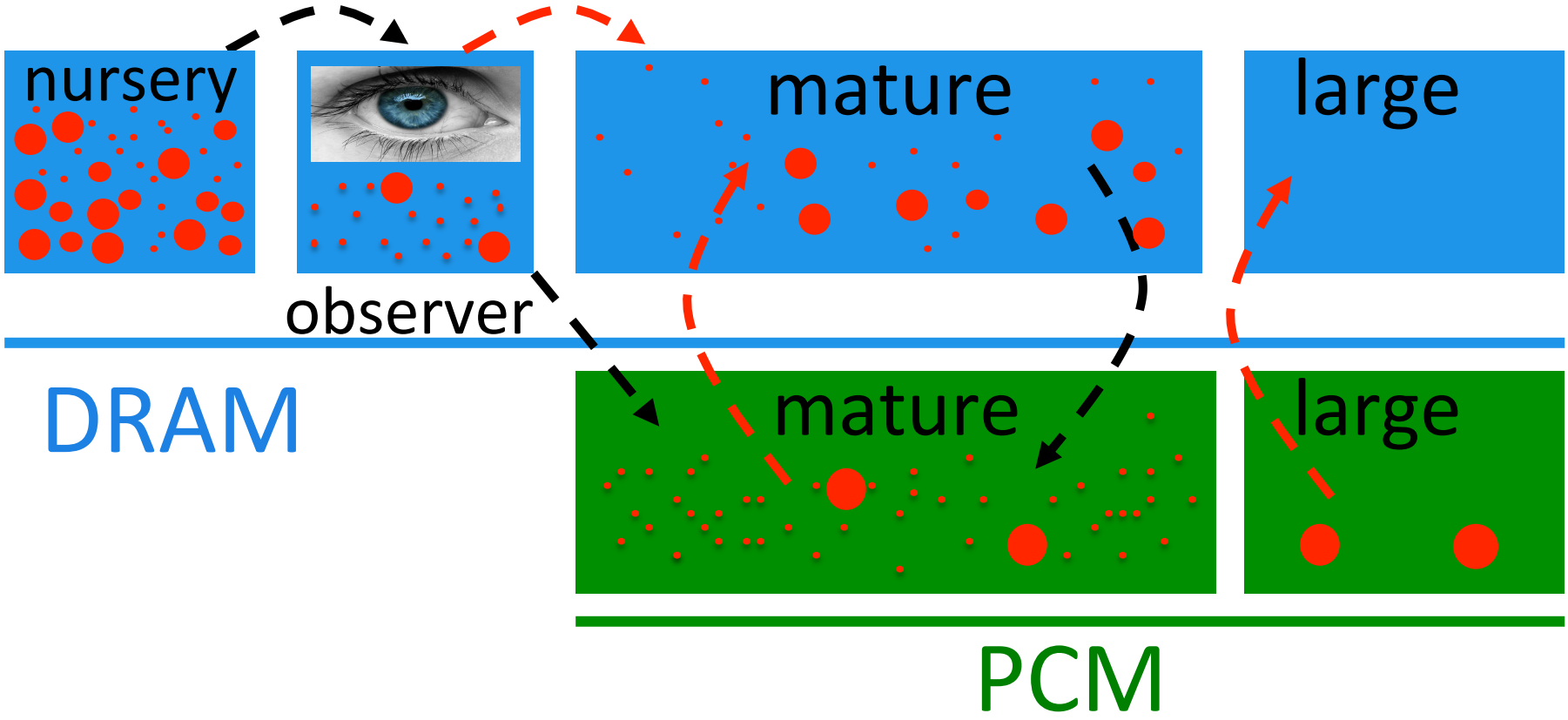
Heap organization in DRAM



KG-N Kingsguard-Nursery



KG-W Kingsguard-Writers



Observing writes

Object format

header	references	primitives

Write barrier sets a header bit on object writes

Write barrier configurations

- Observe references
- Observe references and primitives

Additional optimizations in KG-W

Large object optimization

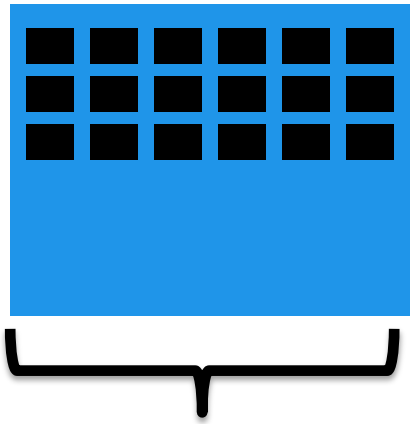
- Allocate selected large objects in DRAM

Metadata optimization

- Allocate PCM metadata in DRAM

Large object optimization

nursery



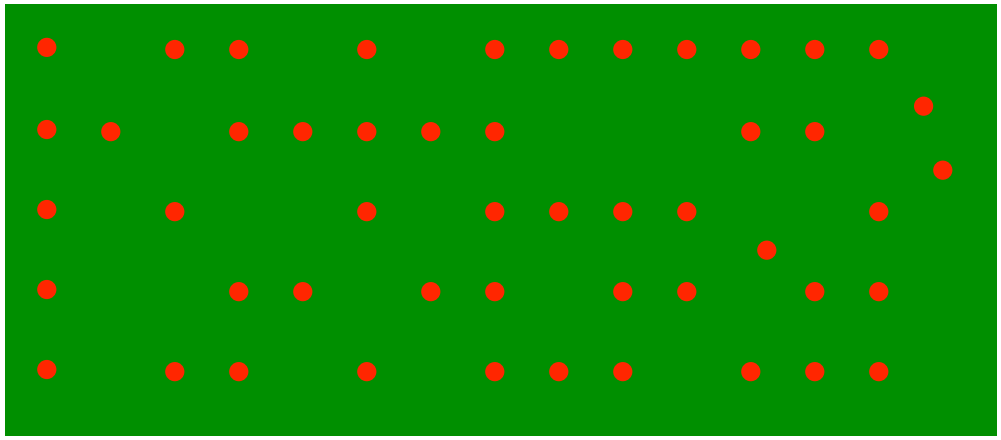
½ of remaining nursery

large

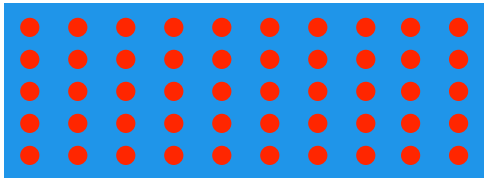
Monitor PCM write rate to tu[redacted]

Metadata optimization

Mature



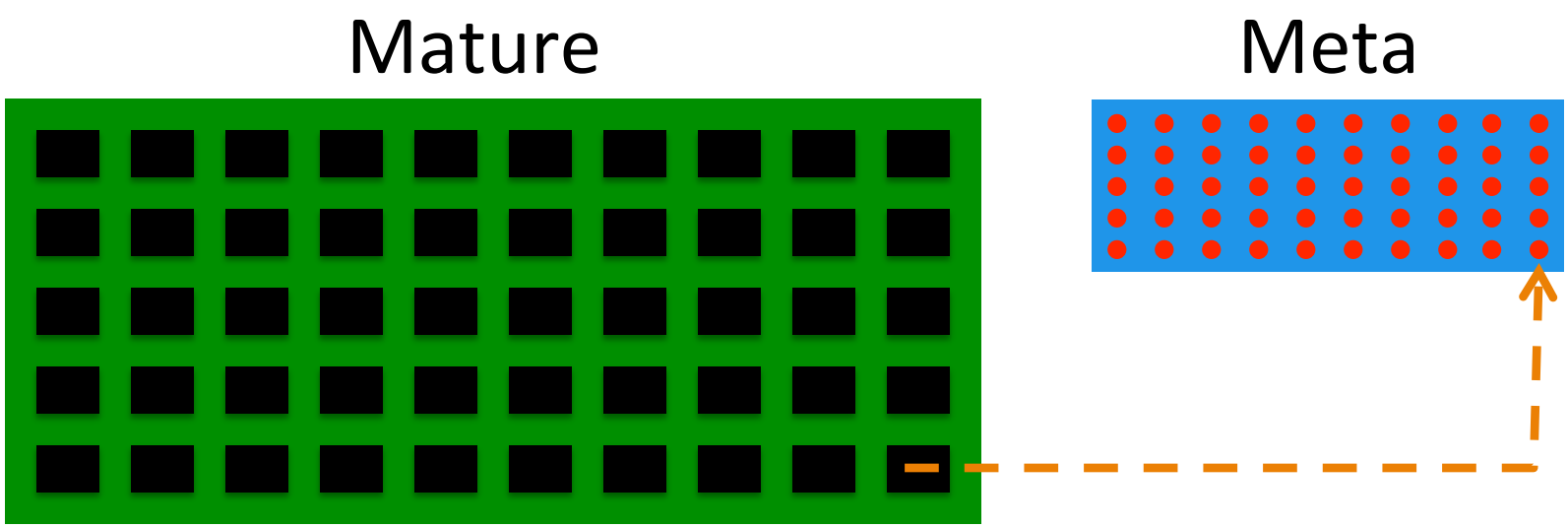
Meta



Full-heap GC: Mark live PCM objects

KG-W: Keep mark bytes of PCM objects in DRAM

Metadata optimization



Full-heap GC: Mark live PCM objects

KG-W: Keep mark bytes of PCM objects in DRAM

address_mark_bit = start_meta + idx_pcm_obj

Evaluation Methodology

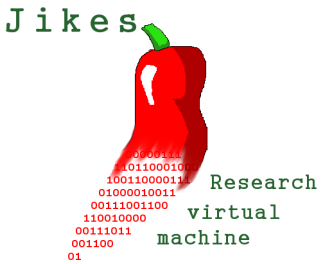
Hardware

(1) Simulator

(2) Real

Software

Jikes research virtual machine



Java applications

Simulation with Sniper

7 DaCapo applications

4 cores, 1 MB per core LLC

Scale simulated rates to a 32 core machine using trends from real hw

Memory systems

Homogeneous

32 GB DRAM

32 GB PCM

Hybrid

1 GB DRAM

32 GB PCM

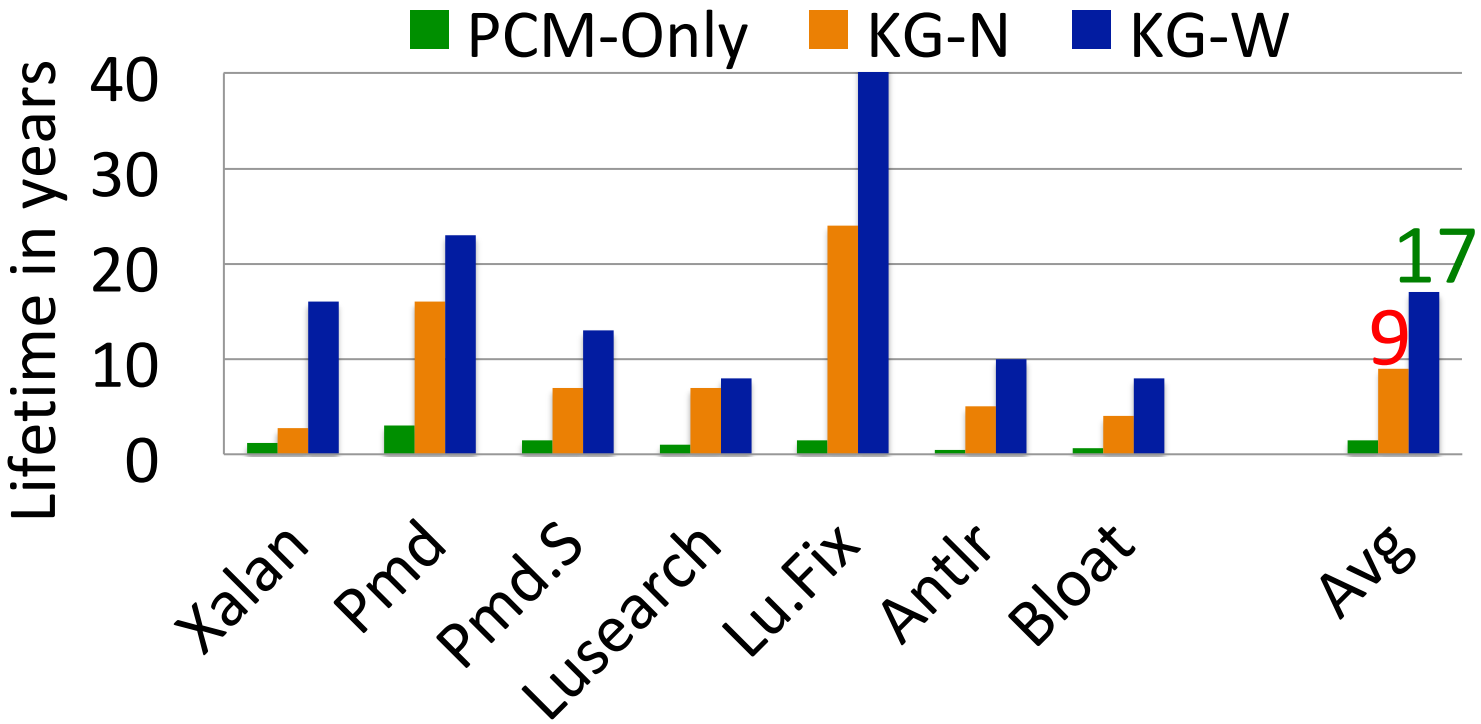
PCM parameters

4X read latency

4X write energy

10 M writes/cell

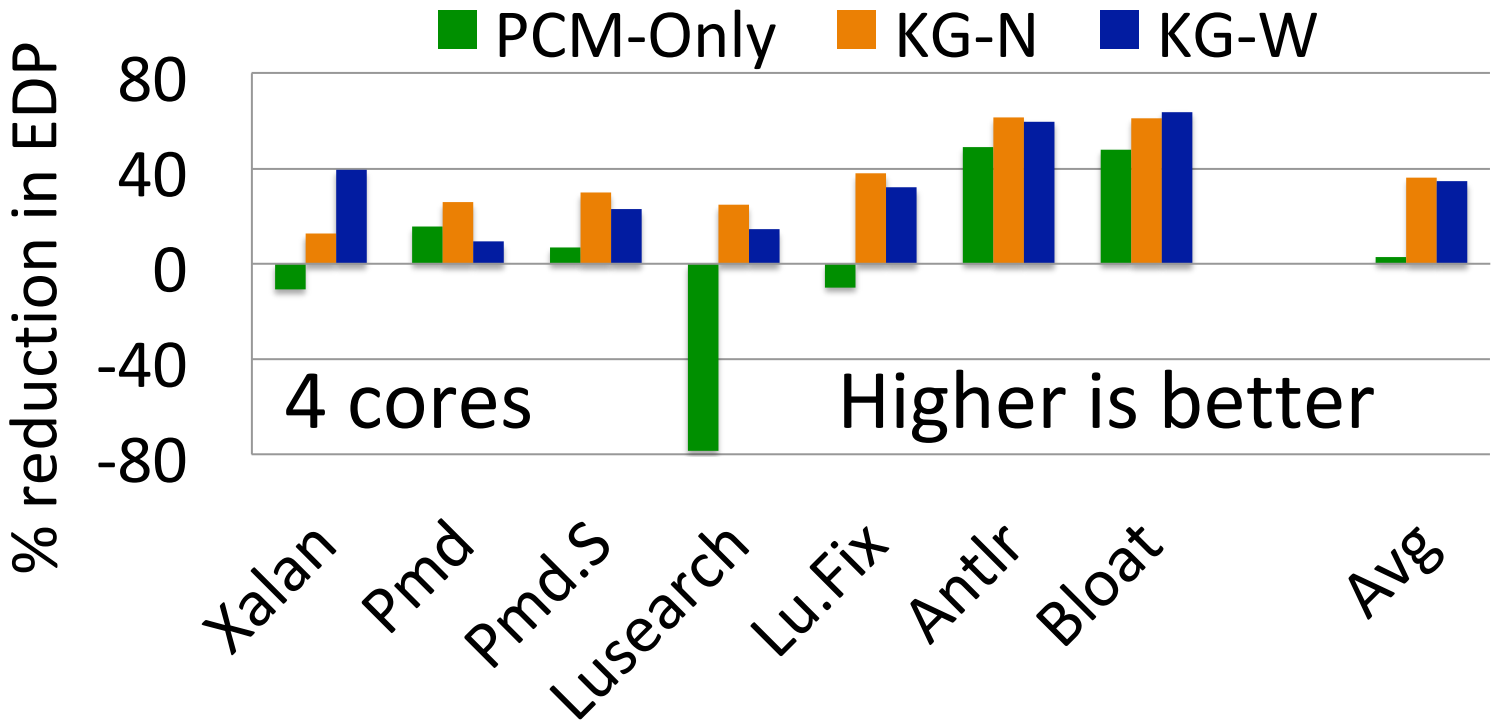
PCM lifetimes



PCM alone is not practical

PCM lasts more than 10 years with KG-W

EDP reduction compared to DRAM



EDP : Energy Delay Product

KG-W has 35% better EDP than DRAM-Only

Emulation on NUMA hardware

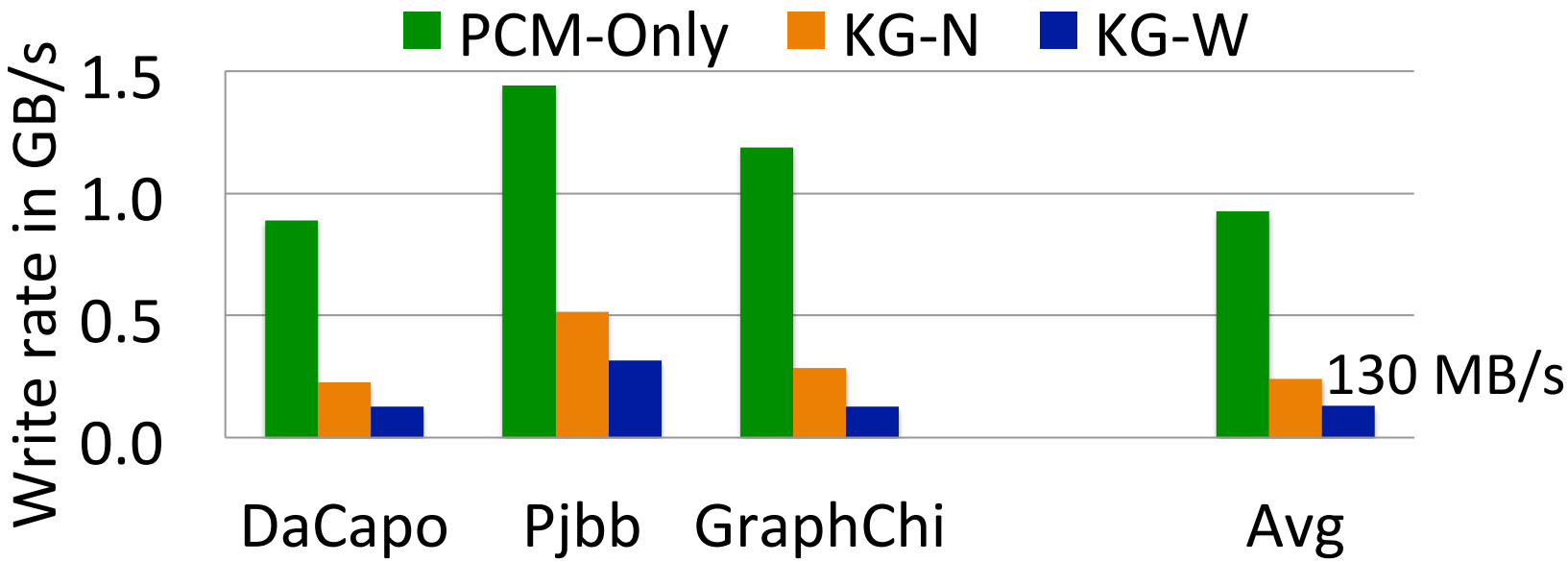
DRAM: Socket 0 PCM: Socket 1

DRAM DRAM

Modi

Use Intel perf monitor to measure writes

PCM write rates on NUMA hardware

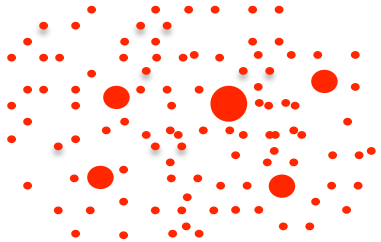


KG-N reduces write rate by 3.8X over PCM-Only
KG-W reduces write rate by 1.9X over KG-N

Crystal Gazer: Profile-Driven Write-Rationing Garbage Collection for Hybrid Memories

Takeaways

Promising to monitor heaps at a fine granularity



Write-rationing GC makes PCM practical as main memory

Similar conclusion with different evaluation methods