Improving DRAM Performance by Parallelizing Refreshes with Accesses

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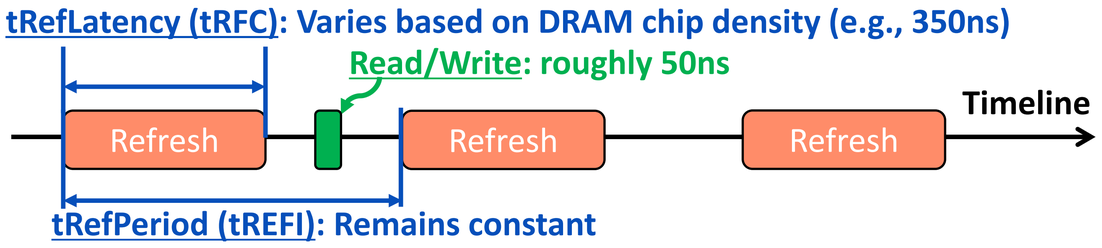
Problem

- **DRAM refresh** interferes with memory accesses, degrading system performance and energy efficiency
- Goal: Serve memory accesses in parallel with refreshes to reduce refresh interference on demand requests

Background and Motivation

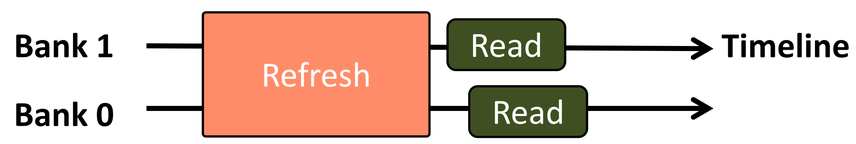
- Memory controllers send **periodic refreshes** to DRAM ranks



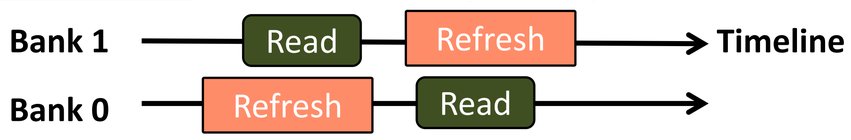
6.7%/23%/41% throughput loss for 4/32/64Gb DRAM

- Two existing refresh modes:

All-Bank Refresh: Employed in commodity DRAM (DDRx, LPDDRx)



Per-Bank Refresh: In mobile DRAM (LPDDRx)



Can serve memory accesses in parallel with refreshes across banks

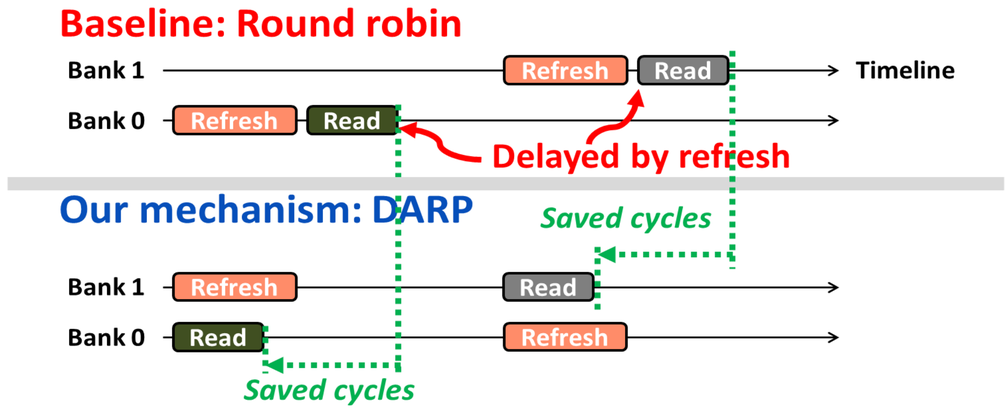
- Shortcomings of per-bank refresh:
  1) Per-bank refreshes are **strictly scheduled** in a **static round-robin order**
  2) A **refreshing bank** cannot serve memory accesses

Enable more parallelization between refreshes and accesses using practical mechanisms

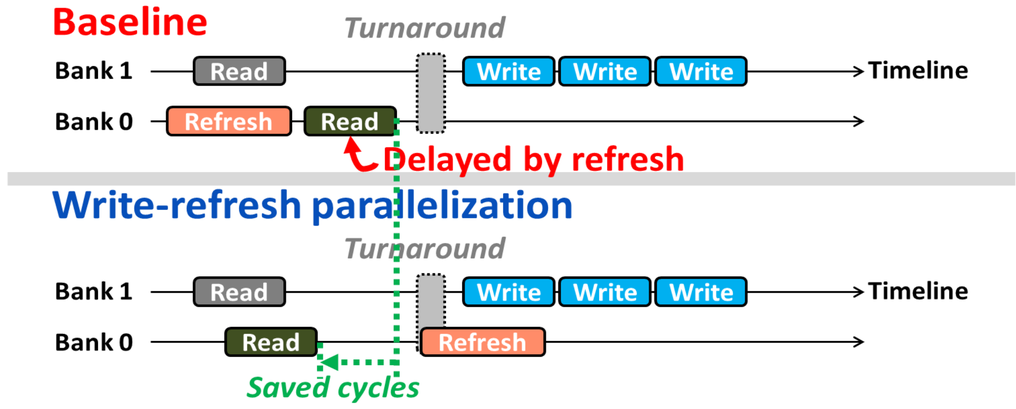
Our Solutions

1 Dynamic Access Refresh Parallelization (DARP):

- Improved scheduling policy for **per-bank refreshes**
- Component 1: **Out-of-order per-bank refresh**
  - Schedule per-bank refreshes to idle banks opportunistically in a **dynamic order**

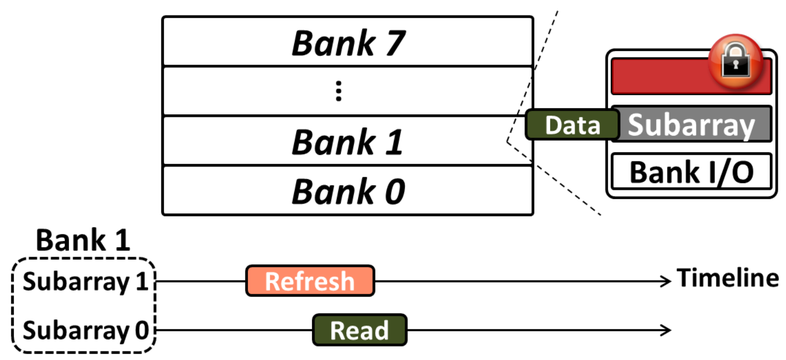


- Component 2: **Write-refresh parallelization**
  - Avoids refresh interference on latency-critical reads by refreshing with writes
  - Proactively schedules refreshes when banks are serving buffered writes



2 Subarray Access Refresh Parallelization (SARP):

- Parallelizes refreshes and accesses **within a bank**



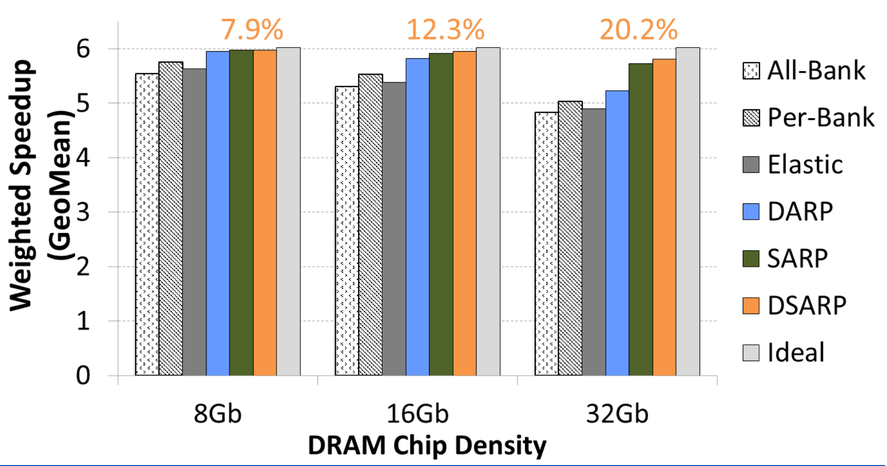
- 0.71% DRAM die area overhead

Results

Methodology

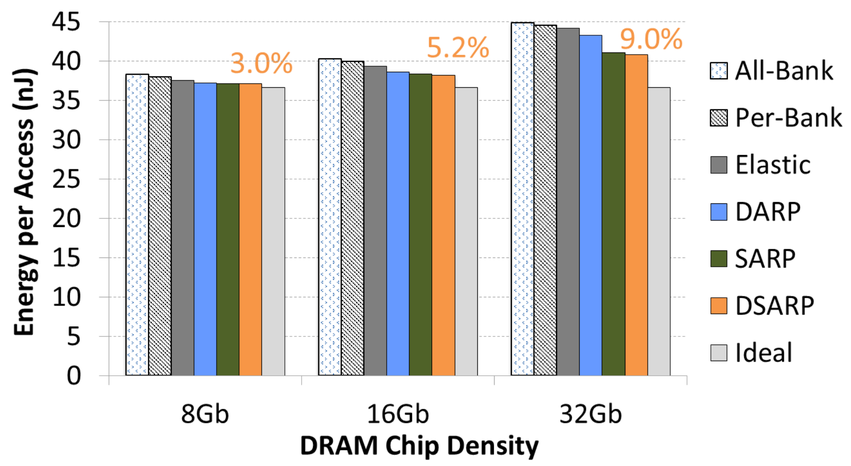
- 8 OoO CPU cores
- Caches: L1 – 32KB, Shared L2 – 4MB
- DRAM: DDR3-1333, 64-bit channel, channels/ranks/banks = 2/2/8
- Workloads: SPEC CPU2006, STREAM, TPC-C/H, random access

System Performance



Consistent system performance improvement across DRAM densities (within 0.9%, 1.2%, and 3.8% of ideal)

Energy Consumption



Consistent energy reduction

**** Please read our paper in HPCA 2014 for more results***

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