Characterizing the Behavior of CloudSuite3 with Midgard

Yuxuan Wang, Nicolas Bouron, Ke Ma

CS-471 Fall 2021, EPFL

Intuition for new memory hierarchy

V2P address translation becomes a bottleneck

- Memory capacity significantly grows in the past decade
- Entries in Translation Lookaside Buffers are limited

Adding a new layer in current memory hierarchy

- New memory architecture — Midgard[1] proposes a new layer to provide translation/protection at VMA granularity
- New cache hierarchy uses Midgard addresses

Explore the reasonable LLC size for new hierarchy

- Cache miss ratio decreases as LLC size increases
- Large LLC brings additional cost

Address translation drives memory hierarchy design

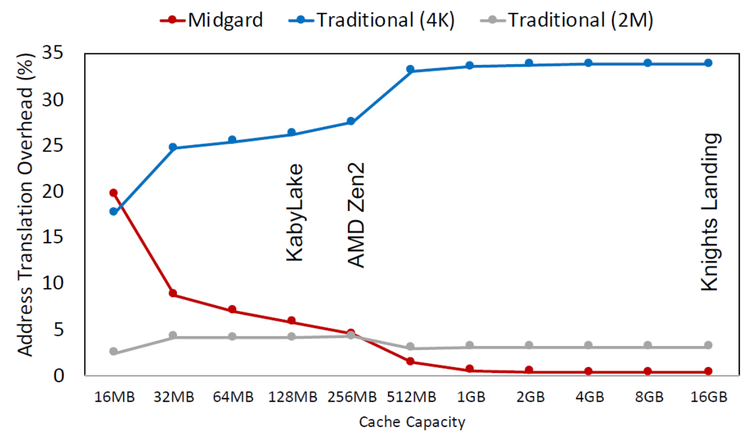
Characterize the cache behavior

Evaluation based on LLC size for Midgard needs testbench

- Tested under real-world and widely-used workloads

CloudSuite: Benchmark suite contains applications which are popular among today's datacenters.

Under the dataset of 200GB, Midgard can provide nearly 0% Address Translation Overhead when Cache Capacity is 4GB (2% of the dataset size).

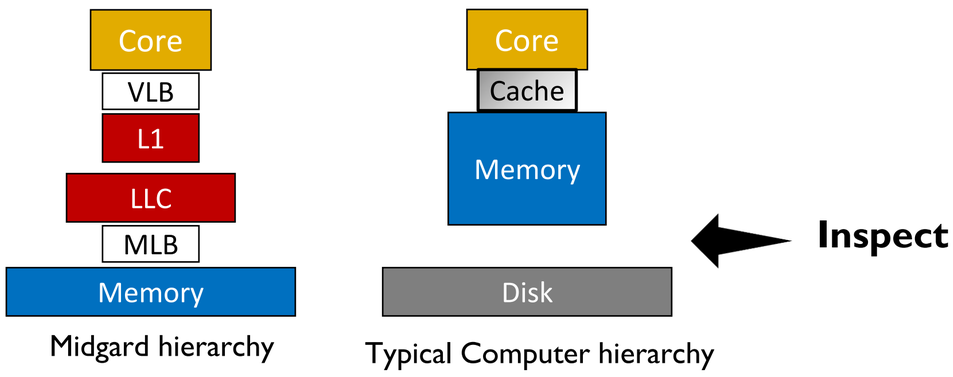


Characterizing under real-world workloads

Utilize typical computer architecture

Memory hierarchy in testing

- Use container to control the resources a program can access
- Assume hard disk as the memory abstraction
- Memory can be regarded as the cache abstraction for the memory in Midgard



Cache miss rates in Midgard can be evaluated by page faults rate in traditional hierarchy

Page faults rate as metrics

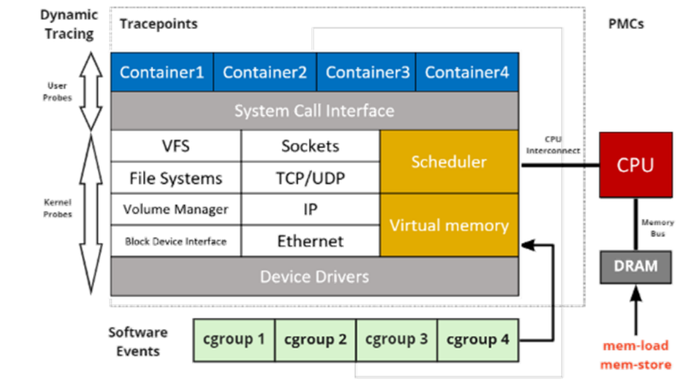
Metrics monitor tools

Docker runtime metrics

- Docker provides tools to limit the memory usage
- Control groups in Linux containers expose memory measurements including major page faults

Perf tools monitor system events

- Perf records the total memory accesses during the server computation

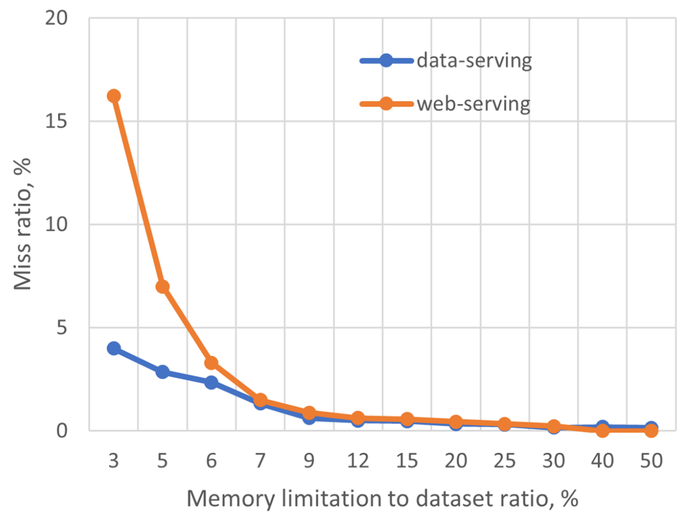


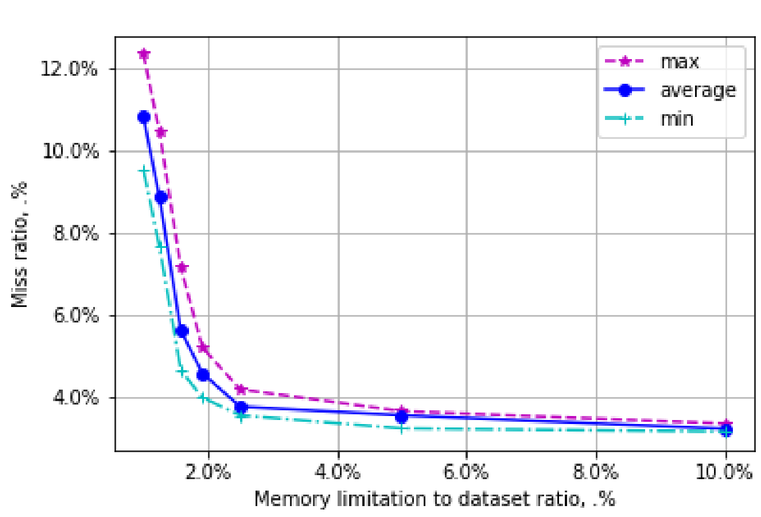
Perf & cgroup works together

Evaluation

Methodology

- Use of a scientific infrastructure designed for cloud-related experiments: CloudLab.
- Use of multi-core Intel processors with 128GB of RAM on average and ~1 TB of storage for the datasets.





Characterisation of memory usage by workloads

- Temporal locality is observed at the simulated cache level
- An inflection point separates a memory-intensive region from one where few new data are requested
  ⇒ Around 5% of the considered dataset size.

Conclusions

- Empirical results over multiple workloads compatible with Midgard claims.
- Costlier LLC misses in Midgard system can therefore be compensated by faster virtual to midgard addresses translations thanks to a new level of indirection (Virtual Memory Areas of unrestricted size).

Under real-world workloads, LLC of ~5% of dataset size provides <3% miss ratio

[1] Gupta, Siddharth, et al. "Rebooting virtual memory with midgard." *2021 ACM/IEEE 48th Annual International Symposium on Computer Architecture (ISCA)*. IEEE, 2021.