Actionable Data Access Monitoring Output Data and Format

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Device and Specific Purpose Memory MC

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Why Data Access Pattern

- Restricted seats, various audiences
- To see how we are doing
- To fore-see what we should do
- To get actionable insights and make it

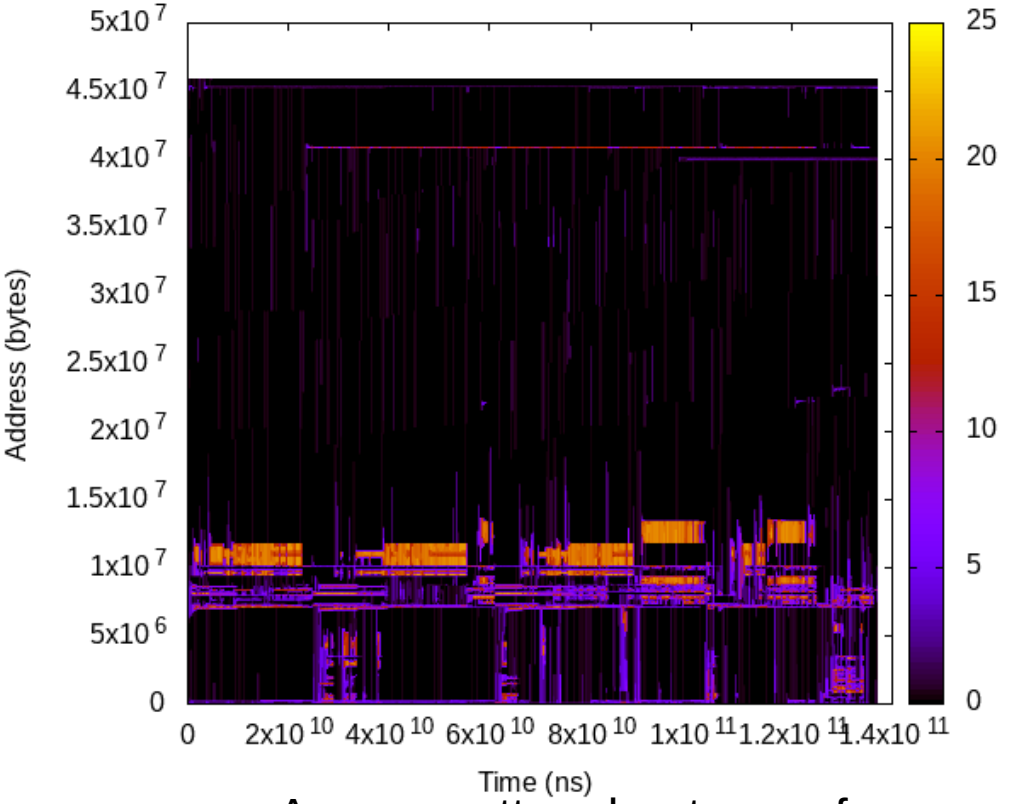
DAMON in Nutshell

What It Does

- Spawn a kernel thread that
- See if each page is accessed, every 5ms
- Inform users the findings, every 100ms
- Time intervals can be [auto-]tuned

Providing Access Information

- Location
- Frequency
- Stability
- Recency



Access pattern heatmap of Splash2x/Raytrace

Overhead and Accuracy

- Utilizes adaptive sampling/aggregation
- The upper-limit overhead is tunable
  - Regardless of the memory size
- 0.0x% single CPU use on real workloads
- Light, accurate, scalable, automated

Availability and Usages

- Available on >=5.15 upstream kernels
- Enabled on most distro kernels
- Being used by products and researches

DAMOS: Second Face of DAMON

- DAMon-based Operation Schemes
  - “Page out cold memory”
  - “Use huge pages for hot memory”
- Turn DAMON into access-aware memory management system operations engine

DAMON in One Sentence

“DAMON is a Linux kernel subsystem for efficient access monitoring and access-aware system operations.”

Community

- Waiting for any **selfish** discussion
- Public channels
  - Mailing list: damon@lists.linux.dev
  - Project website: https://damonitor.github.io/
- Private channels
  - Maintainer email: sj@kernel.org
  - DAMON Beer/Coffee/Tea Meetup

Available Formats
(Access Pattern Visualizations)

It’s Format, Stupid!

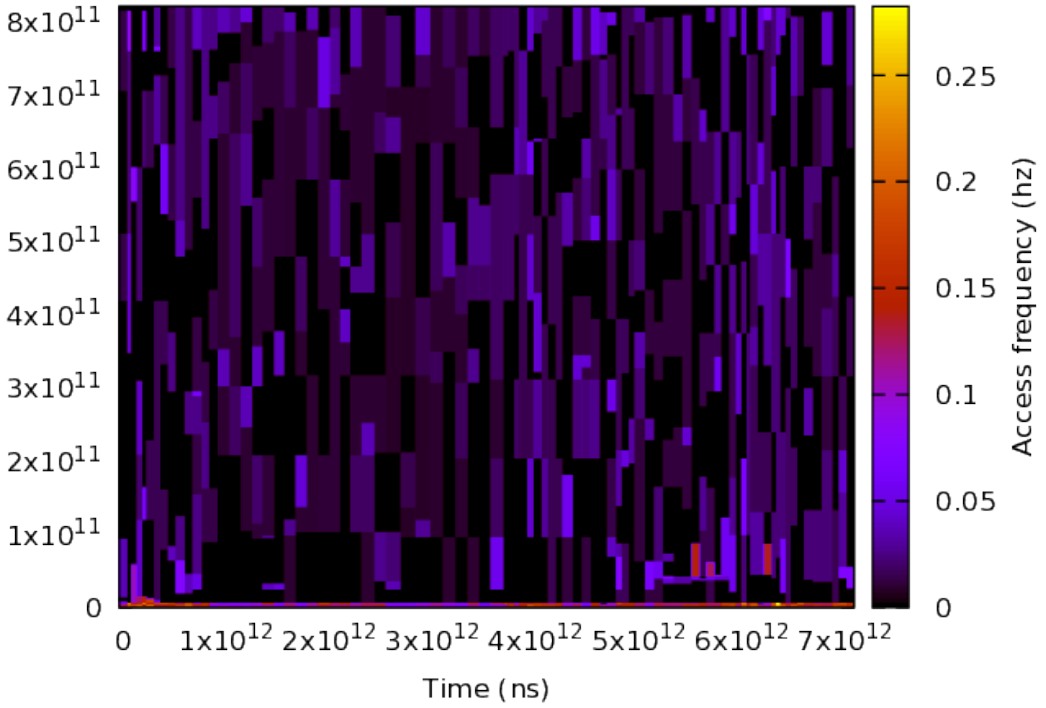
- Having data does nothing
- Same data causes different insights
- Most challenging part
  - Convincing “human”, not “machines”
  - Anyway I’m keeping trying...

Formats for All DAMON Info

- Straightforward (or, lazy) format
  - For location, frequency, stability, and recency
- Namely, heatmap and snapshot

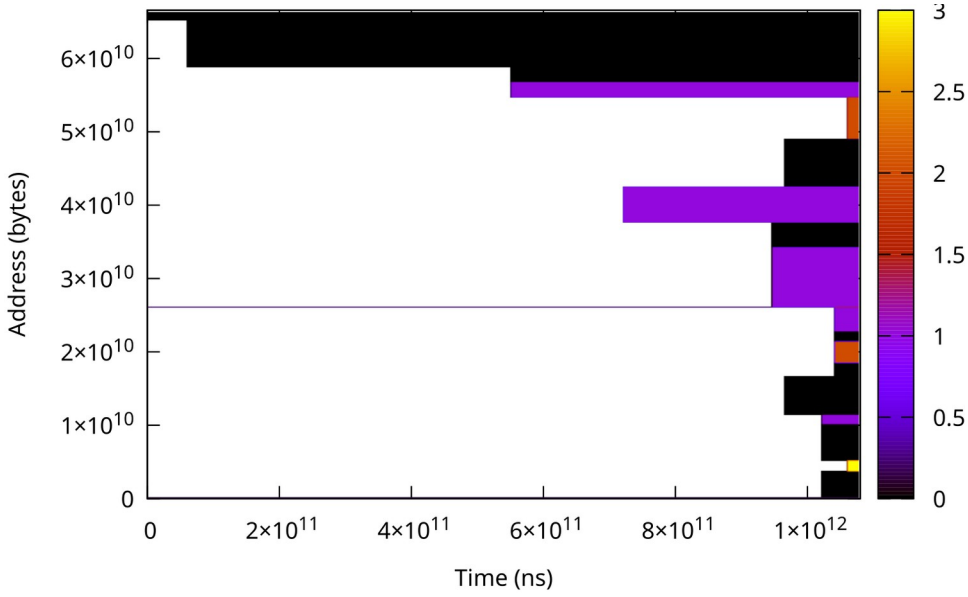
Heatmap

- X-axis: time
- Y-axis: address
- Color: frequency
- Scoping is important (or, challenging)



Snapshot

- A slice of heatmap
- Scoping is still the thing

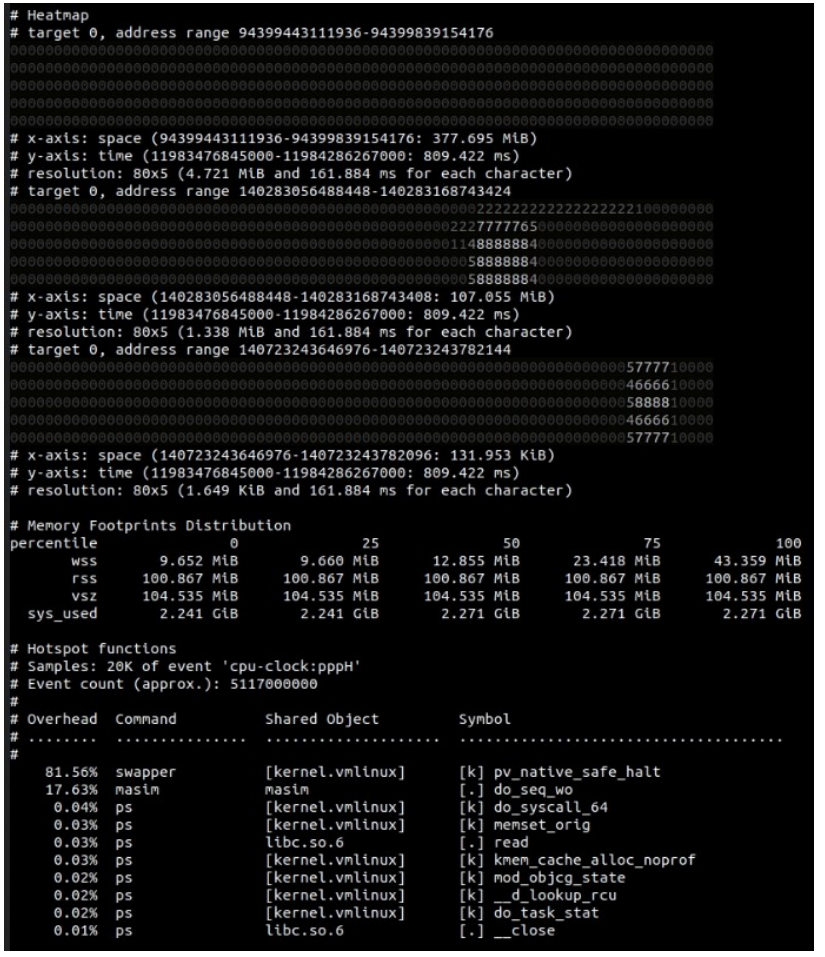


Formats for DAMON++ Data

- DAMON cannot capture the world alone
- Use it together with other tools to record
  - Memory alloc/free/RSS data
  - Hotspot functions
- And show all together as time series data

Holistic Snapshot[s]

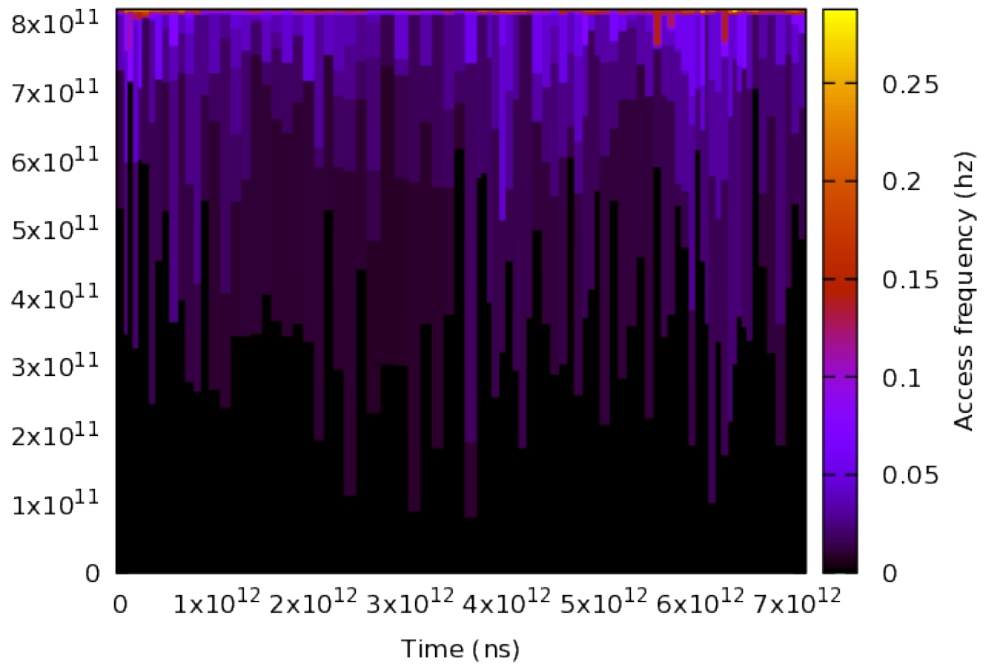
- Ani-GIF



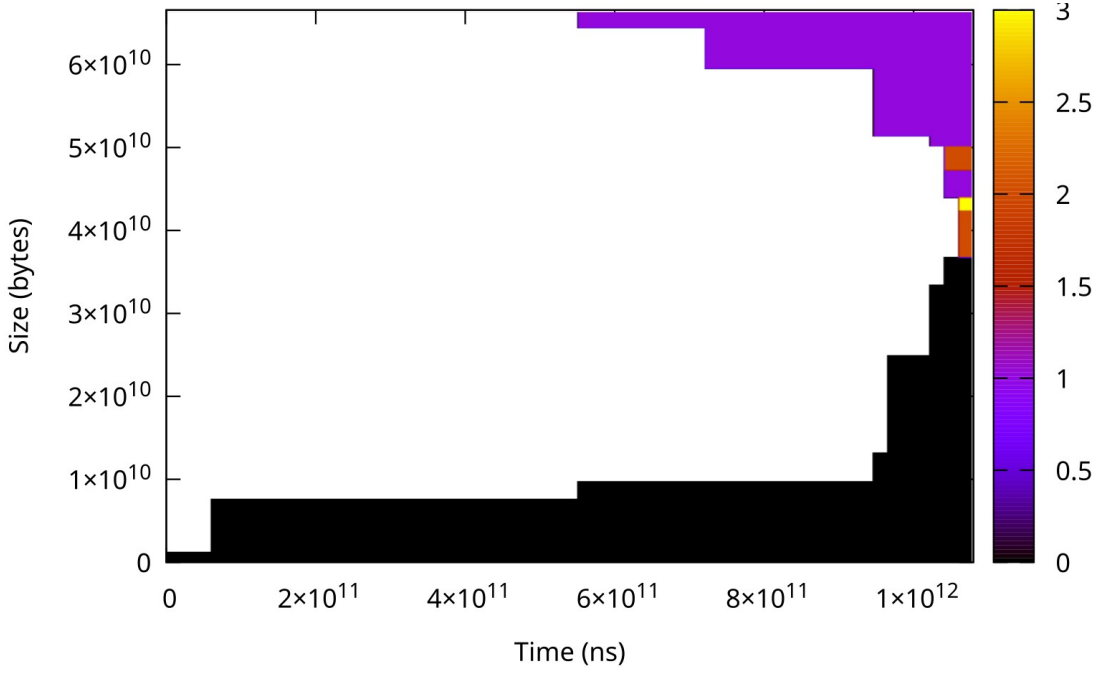
Formats for DAMON-- Data

- DAMON data is just right for machines
- Too much for human in some cases
- Visualize after dropping some information
  - Specifically, “location”
- Namely, hotness-sorted heatmap and snapshot

Hotness-sorted Heatmap



Hotness-sorted Snapshot



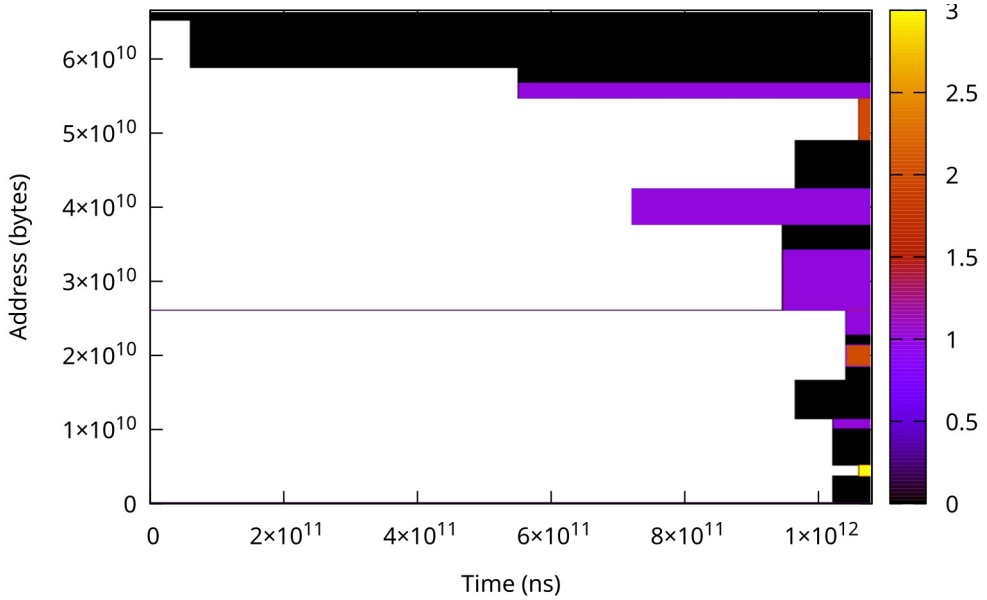
For Coarse-grain DAMON-- Data

- Lines: informative
  - Encourage “creative” interpretation
- Discrete numbers are *alarm*-able
  - Better for busy “fleets”

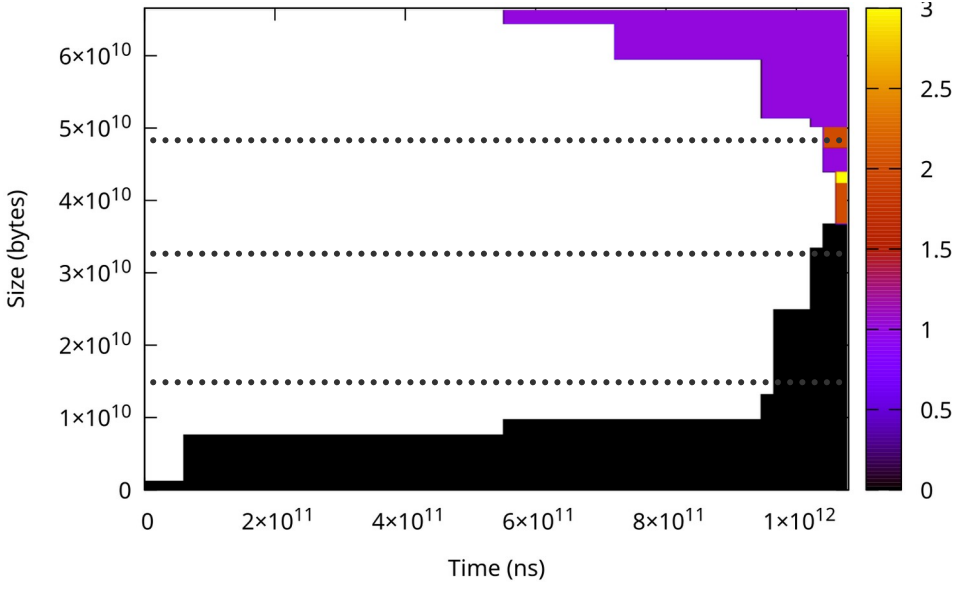
Idle Time Percentiles: Concept

- Idle time: how long it was not accessed
- Percentile: that of the statistics

Unsorted snapshot



Sorted by access frequency



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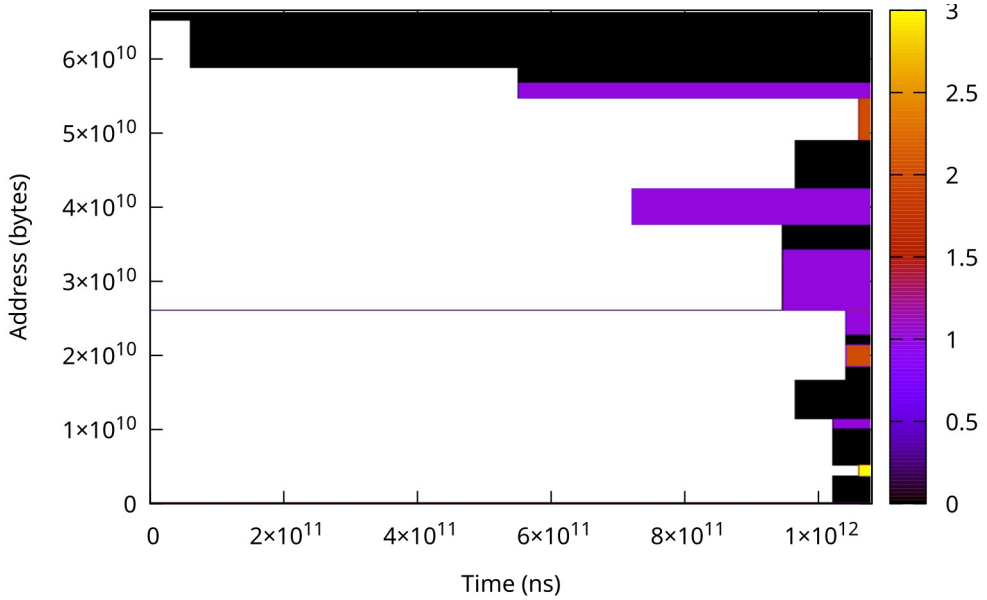

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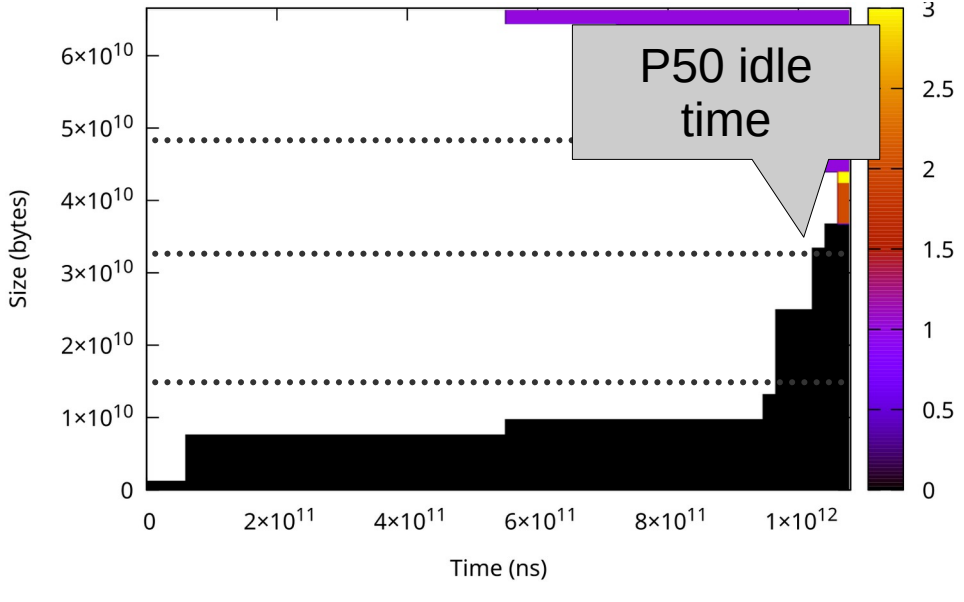

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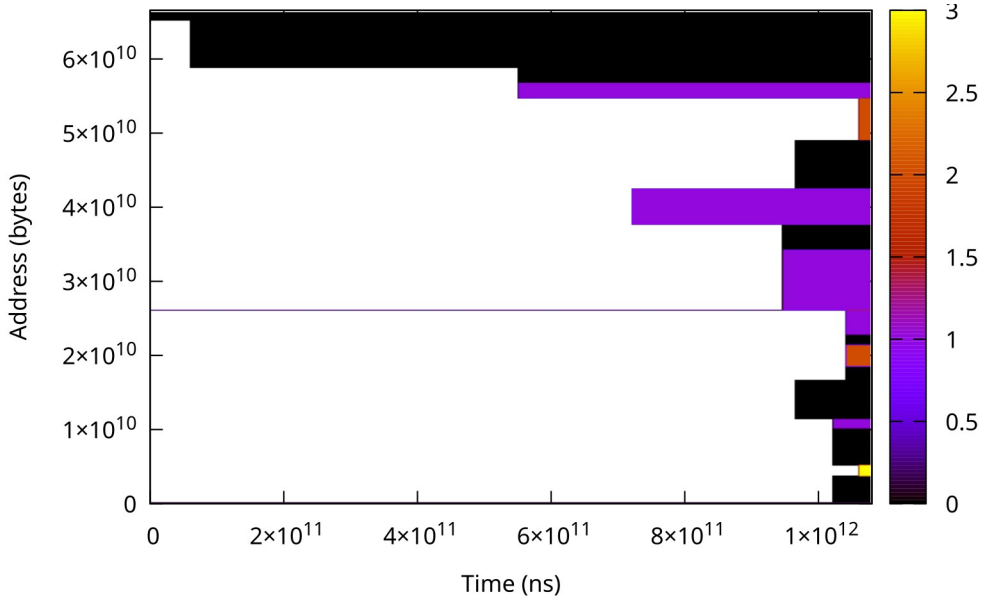

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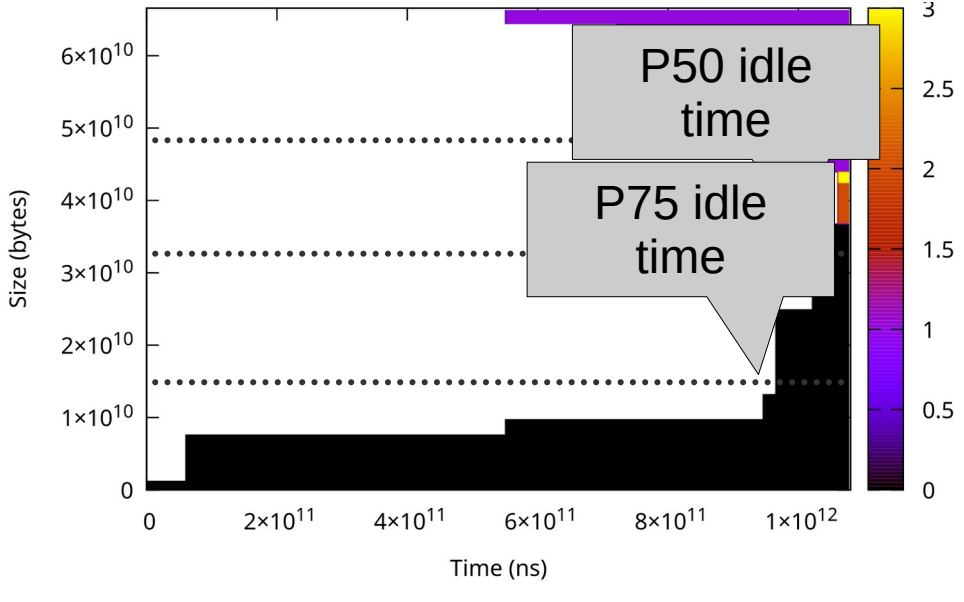

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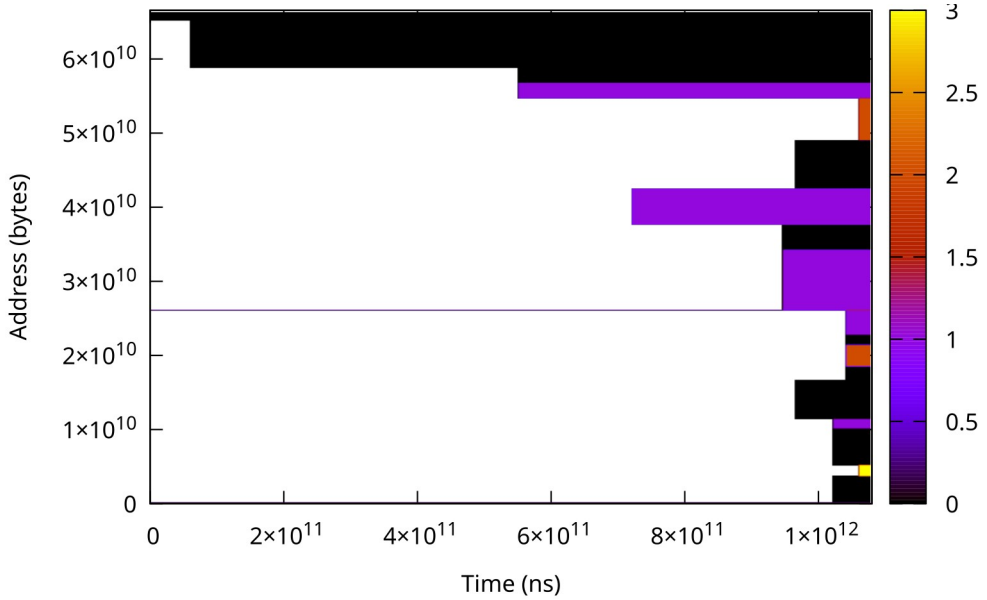

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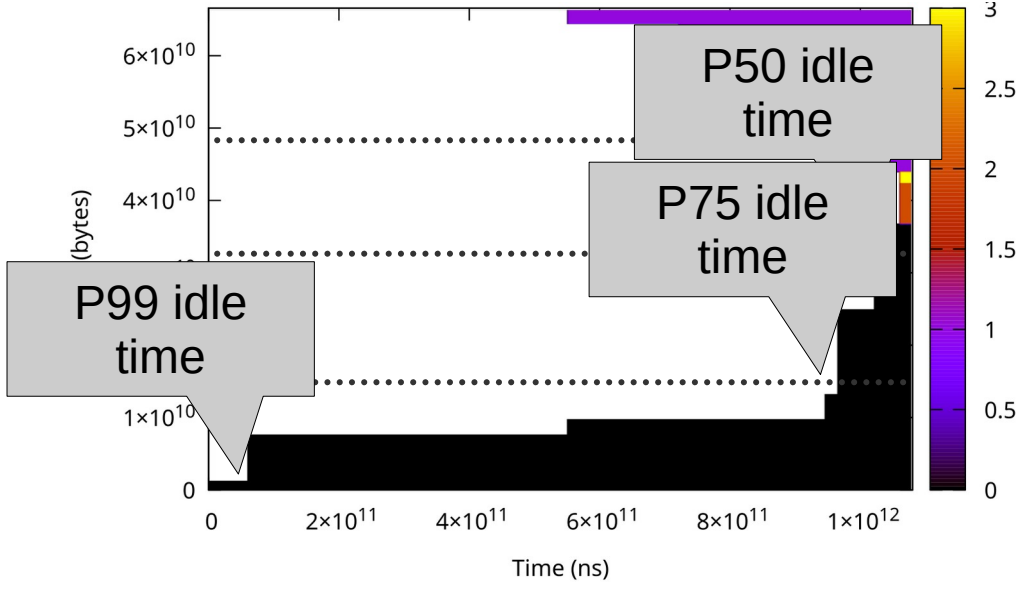
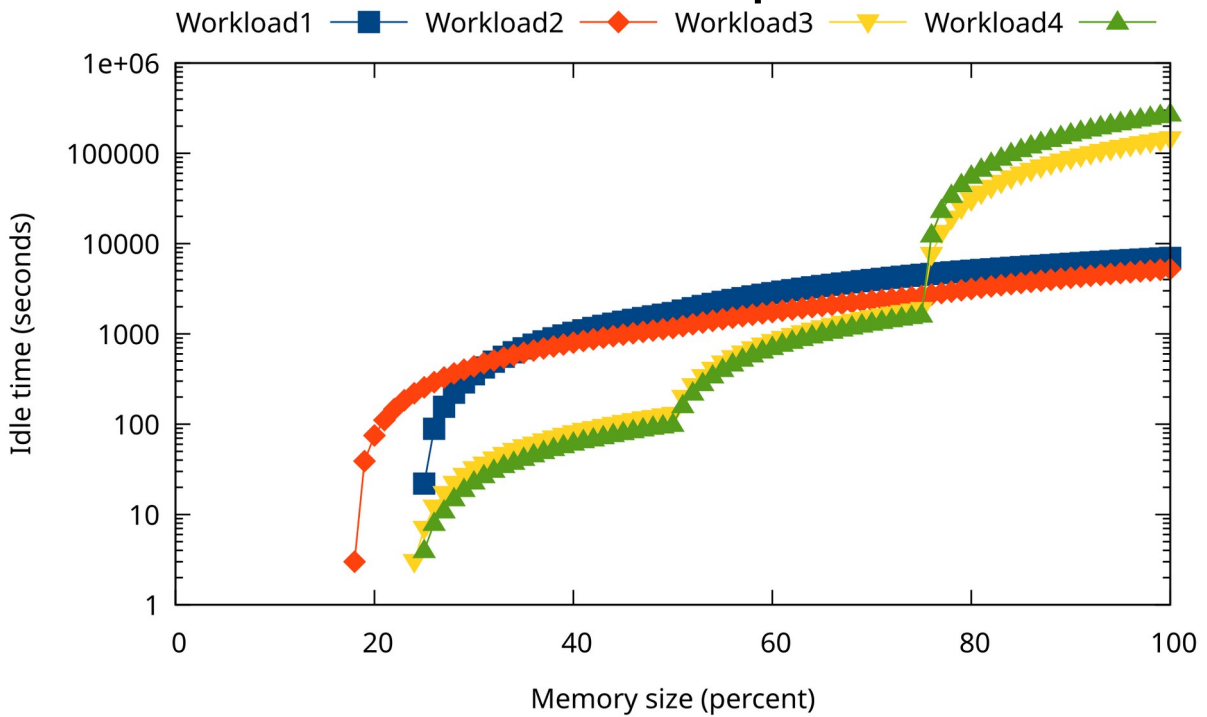


Idle Time Percentiles in Real

- Note: Y-axis in logscale
- Show common and different patterns of workloads

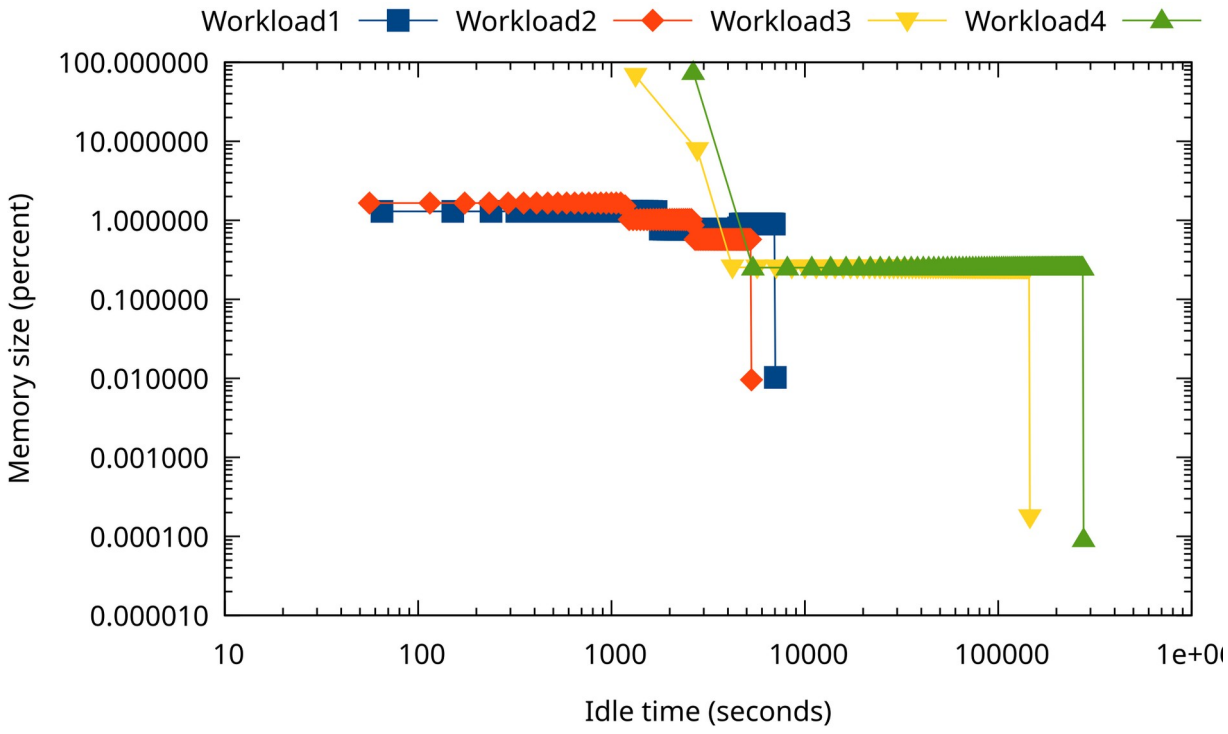


Cold Memory Tail

- X/Y-axis inversion of idle time percentiles
- X axis: Idle time
- Y axis: Size of memory of the idle time

Cold Memory Tail in Real

- Note: Both X/Y-axis in logscale



Estimated Memory Bandwidth

- A region in DAMON snapshot
  - of size 1 GiB
  - that was accessed 10 times per second
- Estimation: 10 GiB/s bandwidth use
- Shouldn’t be accurate but best effort

Formats for Brave People

- Turn on DAMOS-based operations
  - e.g., proactive reclamation, memory tiering
- Hear if someone yells
- Surprisingly most successful use case
- Here is the help: DAMOS stats

Wrapup

- DAMON provides access information
- There are 2+ ways to show that
  - Maybe good for fans of oysters but snakes

Discussion Time

- Any of the formats seems useful? Why?
- Any new format suggestions?
- More info or less info?
- What is reasonable “actionable” goal?