Department of Computer Science

HPS

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Tracking User-Perceived I/O Slowdown via Probing

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Limitless Storage
Limitless Possibilities

https://hps.vi4io.org

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HPC-IODC

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LIMITLESS **POTENTIAL** | LIMITLESS **OPPORTUNITIES** | LIMITLESS **IMPACT**

Outline

Motivation

- Performance of shared file system is load dependent
  - Also background activity may cause delays
- Difficult to judge: observed performance is slower/faster than normal
  - A subcomponent of a file system may be loaded (e.g., metadata)
- Users/staff may wonder for the cause of the experienced performance
  - "Is that caused by my application?"
  - Can lead to support requests
- Maybe a quantification of the file system load similar to `uptime` would help?

Approach

- Running a minimal invasive benchmark (a probe) with a high frequency
  - Mimic the user-visible client behavior
  - Measuring latency for metadata and data operations
  - Overloaded servers will delay the response time
- Generate and analyze generated statistics
- Derive a slowdown factor (file system load)

Why not use server-sided information?

- Client perspective is different (involves network, too)
- Servers experience different types of IO
  - We need to compare standard values!
- Tracking response latencies for op type/size histograms would do
  - Vendors: integrate such a reporting (vendor neutral API!)

Outline

Performance Measurement

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Preparation

- Data: Generate a large file (e.g., $>$ 4x main memory of the client)
- Metadata: Pre-create a large pool of small files (e.g., 100k+ files)

Benchmarks

- Repeat the execution of the two patterns every second
- DD: Read/Write a random 1 MB block
- MD-Workbench: stat, read, delete, write a single file per iteration
  - Allows regression testing, i.e., retain the number of files
  - *J. Kunkel, G. Markomanolis. Understanding Metadata Latency with MDWorkbench.*

Executed as Bash script or an integrated tool:
`https://github.com/joobog/io-probing`

Discussion of the Approach

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- Monitoring load: load is with 2 MB/s and 5 MD ops/s negligible
- Resource cost: the monitor needs a client node to execute
  - Use it exclusively or share it?
  - Adds costs
- Representativity: systems have 100's of I/O servers
  - For 100 servers, after 100s statistically most servers were probed
- Understanding high-frequency of latency changes
  - Apply statistics for data reduction
- Interpretation of the slowdown factor
  - Must be easy to understand
  - Must adjust over the life time of a system

Computing the Slowdown

- The user-perceived slowdown is defined as $s = \frac{t_{observed}}{t_{expected}}$
- The expected time is the `median` over the observation period
  - As performance many change due to user load and system aging, the value could be updated, e.g., every month or after system upgrades
- The observed time is the latency from the benchmark
  - To increase robustness computing a statistics over a sliding window
  - The computation can be adjusted to the use case or to ensure a service level
    - median: indicating the slowdown of the faster 50% of operations
      That also means that the other 50% operations are slower than that
    - quantiles, e.g., Q90: slowdown for 90% of the operations

Outline

Test Systems

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- JASMIN, the data analysis facility of the UK
  - Precreation: 200k files, 200 GB data file
  - 60 days of data
  - Script runs exclusively on a node
- Archer, the UK national supercomputer service
  - Precreation: 200k files, 200 GB data file
  - 30 days of data
  - Script runs on a shared interactive node
- Mistral, the HPC system at the German Climate Computing Centre
  - Precreation: 100k files, 1.3 TB data file
  - 18 days of data
  - Tool runs on a shared interactive node

Understanding the Timeseries

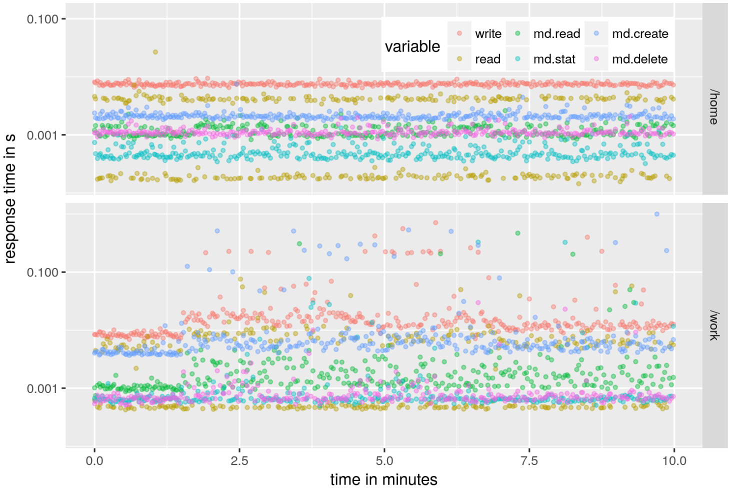

Figure: Jasmin every data point for 10 minutes from one node

- Every probe (1s) for 10 min
- For two file systems
- Home is stable
- Work shows irregularities

Robustness of Statistics on Hosts

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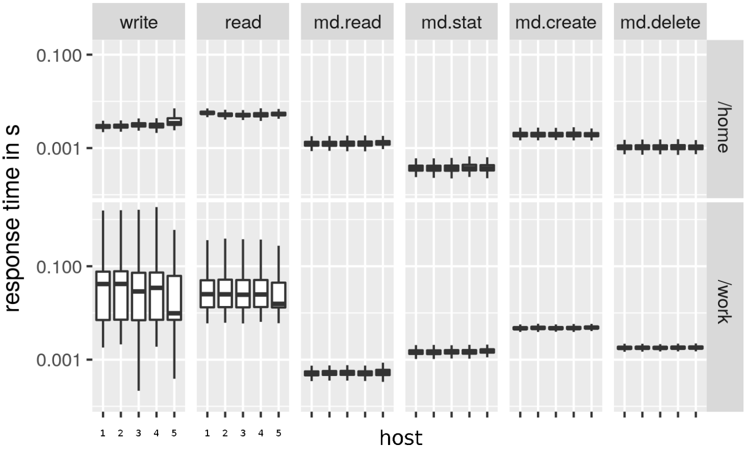

- 5 hosts: 1 hour data
- 2000 measurements
- Statistics are similar
- Home is stable
- Work shows irregularities

Figure: Jasmin boxplot statistics from five different hosts

IO-500 Response Time on Archer

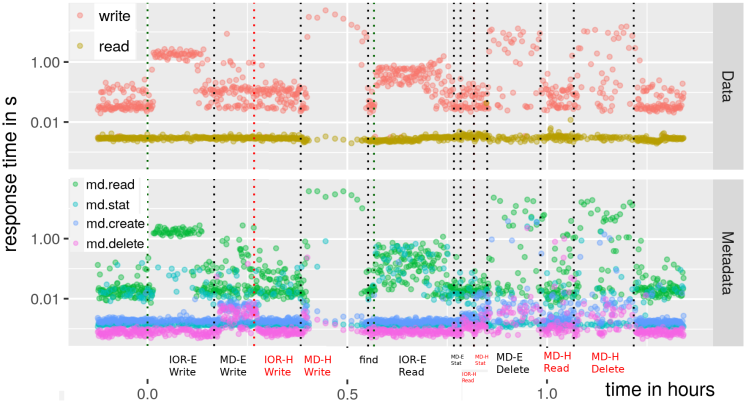

Figure: Response time (all measurements)

- Run on 100 nodes
  score 8.45
- The IO-500 various phases
  Data and metadata heavy
- First, all measurements

Validating Slowdown on All Measurements

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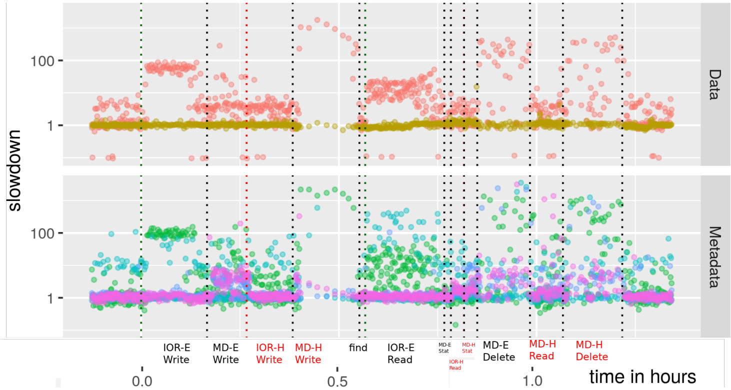

Figure: Slowdown (all measurements)

- Computed median slowdown
  Expected: median of 30 days
- Influence of phases is visible
- MDHard 1000x slowdown
  Influences data latency!
  10s of seconds latency
- IOREasy 100x slowdown
- IORHard not too much
- Data read is stable

Validating Slowdown: Reduced Data

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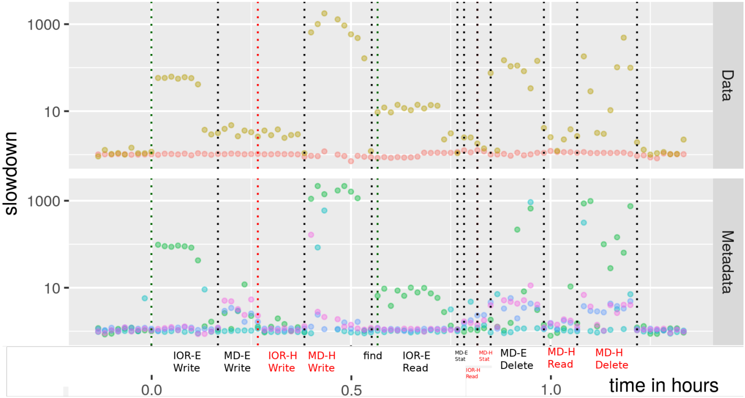

Figure: Slowdown (60s mean statistics)

- Data reduction: 60s mean
- More robust, clearer to see

Boxplots for 4h Statistics

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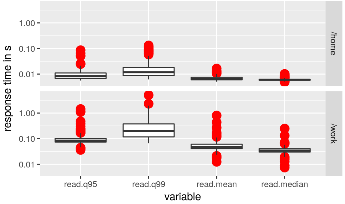
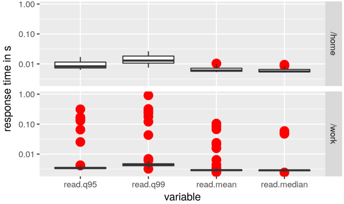
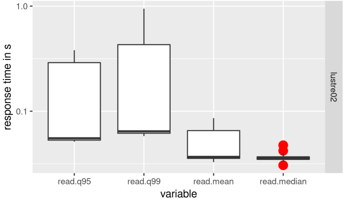


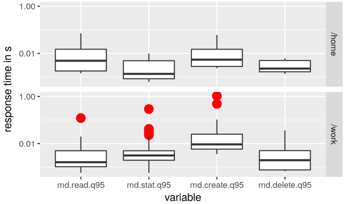
(a) JASMIN read (60 days)



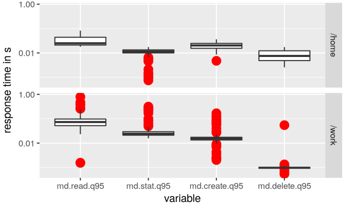
(b) Archer read (30 days)



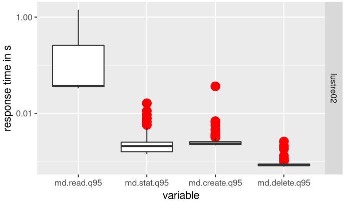
(c) Mistral read (18 days)



(d) JASMIN metadata



(e) Archer metadata



(f) Mistral metadata

Timelines of 4h Statistics

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Figure: JASMIN data timeline

- Compare different statistics
- Maximum latency of 100s (!)
- Q99 and Q95 are more robust
  Still, delay is not acceptable

Timelines of 4h Statistics

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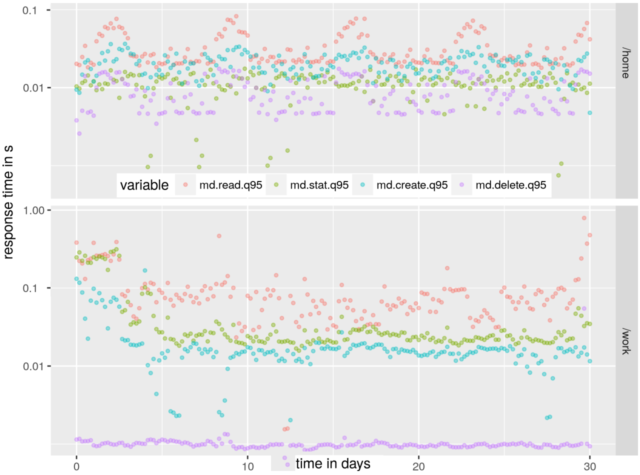

Figure: Archer metadata timeline

- Use Q95, 5% ops are slower
- Home: regular slower except for stat
- Work: slower at beginning

Timelines of 4h Statistics

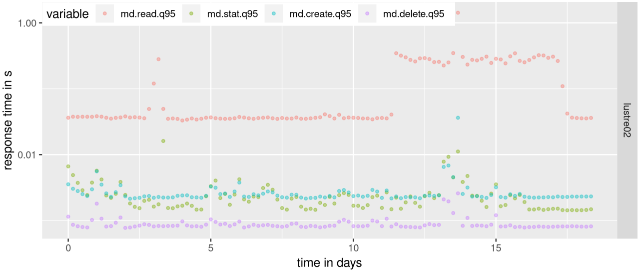

Figure: Mistral metadata timeline

- Use Q95, 5% ops are slower
- Change in behavior at day 12
  Reason: unknown

Slowdown for 4h Statistics

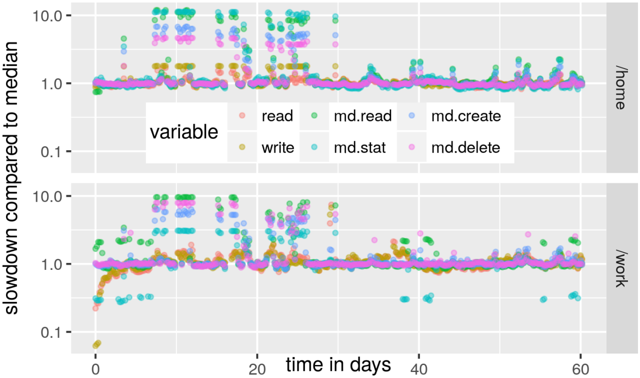

Figure: JASMIN, computed on 4 hour intervals

- Slowdown: Using the median
- Typically value is 1
- Sometimes 10x slower
- Values below 1, unusual (caching)
- Good to see long-term issues

Slowdown for 10 Min Statistics

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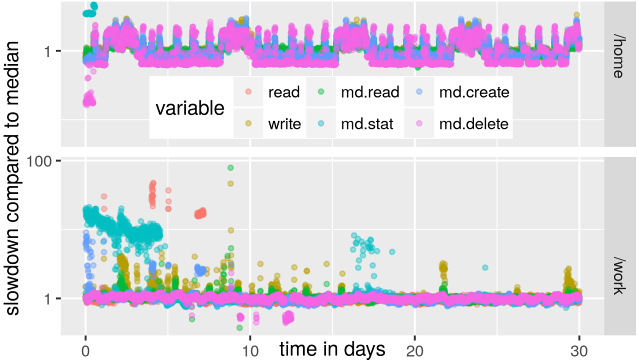

Figure: Archer, computed on 10 min intervals

- Home: periodic behavior visible
  Weekly but also daily
- Work: sometimes 10x slower
- Could be made accessible to users / data center-staff

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Summary

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- Understanding user-slowdown by probing
  - Measuring latency from client-side
  - Reducing frequency using statistics
- Statistical data reduction depending on use case
  - Quantile depending on service level
  - Interval depending on needs
  - No silver bullet at the moment
- Effective to identify slow periods
  - Validated with IO-500 behavior
  - Observed background activity
- Some IOs are very slow (100s)!
  - Did you ever wait so long for a touch/cat?
- Future work: long-term studies and utilize splines