Analyzing Characteristics of Parallel Jobs on the Mistral Supercomputer

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Goals

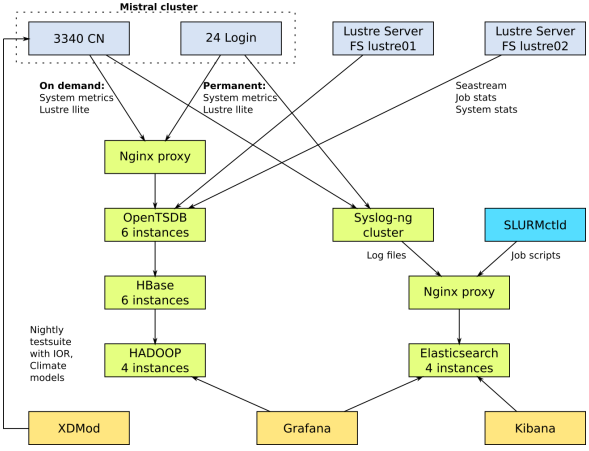
Motivation

- Understanding the workload of the Mistral Supercomputer.

Goals

- Monitoring system development
  - A flexible and extensible monitoring system
  - A portable solution for the next HPC generation
- Establishing analysis workflows
  - Identification of problematic applications and key workloads
  - Understanding of typical I/O patterns
- Tooling
  - Automatic identification of inefficient applications (long term goal)

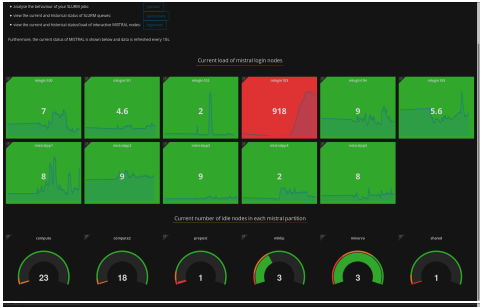
DKRZ Supercomputer and Monitoring



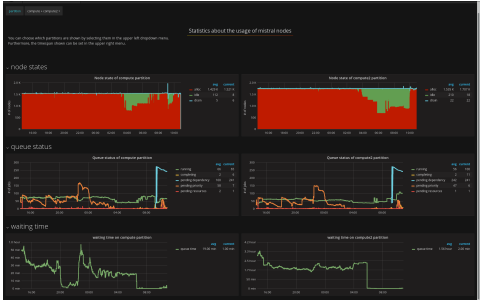
- The Mistral Supercomputer
  - 3,340 client nodes
  - 24 login nodes
  - 2 Lustre file systems
  - Slurm workload manager
- Monitoring System is built of
  - open source components
  - a self-developed data collector
- **Provides statistics about**
  - **login nodes**
  - **user jobs**
  - **workload manager queue**

User Interface: Grafana with Templates

Overview



Slurm



- These views are always available
- Job monitoring is optional
  - Can be enabled by a Slurm parameter

Login nodes

Envisioned User Workflow

- Visualization of system behavior
  - Coarse grained monitoring is always active
  - On demand refinement of the job monitoring
  - Options to change the monitoring behavior
- Visualization of specific jobs
  - Must be explicitly enabled by a Slurm parameter
  - After job finishes the monitoring data is available in Grafana
    - A view in Grafana provides a list of monitored jobs
    - The data is available for 24 hours

Refining Monitoring Settings

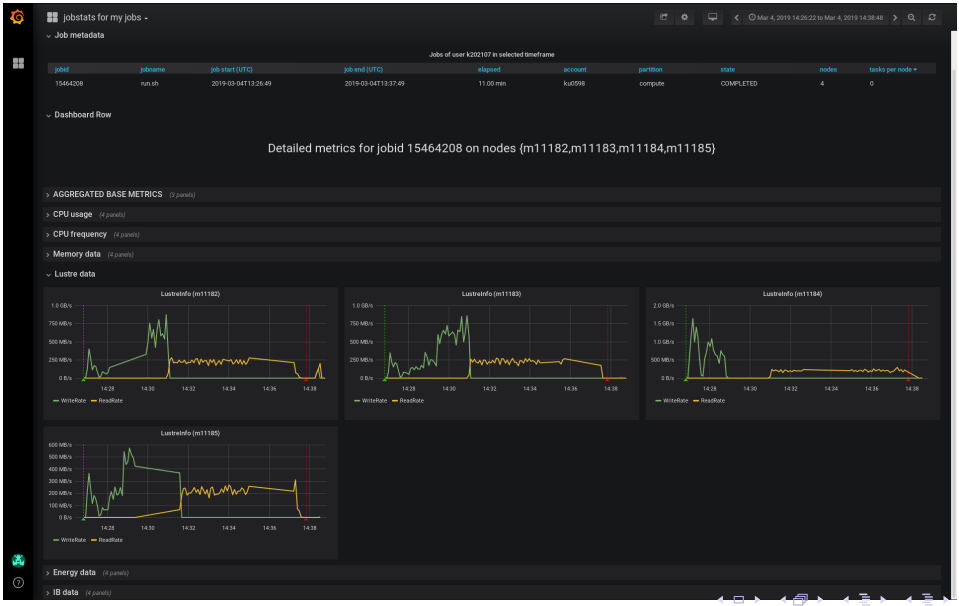
- Slurm monitoring options and capture interval
  - **cpu** : cpu usage (usr, system, idle, iowait)
    - gathered by sockets to e.g. identify non optimal CPU binding, cpu frequency per core/HT to identify throttling
  - **meminfo** : memory usage (available, cached, active)
    - allowing to immediately recognize leaks in application
  - **lustre** : read/write bytes per second
  - **power** : energy consumption

Example

```
#!/bin/zsh
#SBATCH -N 4
#SBATCH --monitoring=meminfo=10,lustre=5,cpu=5,power=5

srun -N 4 --ntasks-per-node=4 ior -s 10000 -b 2097152 -t 2097152 -a POSIX
```

User Interface: Job Statistics



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Captured I/O Metrics

- I/O metrics are captured and archived by default for each job
- Some metadata metrics are cumulated
- Relevant Lustre metrics are captured (focus on key aspects)

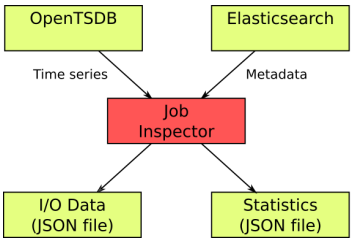
Source file: /proc/fs/lustre/llite/lustre*-*/stats

```
md_read = getattr + getxattr + readdir + statfs + listxattr + open + close
md_mod = setattr + setxattr + mkdir + link + rename + symlink + rmdir
md_other = truncate + mmap + ioctl + fsync + mknod
md_file_create = create
md_file_delete = unlink
```

Source file: /proc/fs/lustre/llite/lustre*-*/read_ahead_stats

```
osc_read_bytes, osc_read_calls
osc_write_bytes, osc_write_calls
read_bytes, read_calls
write_bytes, read_calls
seek
```

Analysis Workflow



- A daemon process iterates over all jobs
- Each job is fetched and analysed
  - Elasticsearch provides meta data
  - OpenTSDB provides I/O time series
- Output
  - I/O data is stored in separate JSON files
  - Statistics (Object of investigation)
    - Currently done in R
- The tool is in an early development stage

Aggregated Data in JSON format: a Sample


```
{
 "metadata": {
   "_source": {
     "time_limit": 5400,
     "@end": "2018-12-04T11:32:23",
     "cpu_hours": 0.057778,
     "cpus_per_task": 1,
     "total_cpus": 8,
     "@eligible": "2018-12-04T11:31:23",
     "elapsed": 26,
     "jobid": 14407499,
     "state": "COMPLETED",
     "jobname": "mkm0003_post",
     "ntasks_per_node": 8,
     "@start": "2018-12-04T11:31:57",
     "ntasks": 8,
     "groupname": "mpioes",
     "nodes": " m11515 ",
     "job_name": "mkm0003_post",
     "user_id": 23738,
     "group_id": 2100,
     "exit_code": "0:0",
     "total_nodes": 1,
     "account": "ba0989",
     "username": "m300467"
   }}}
```

```
"ts": {
 "read_bytes": [
   {
     "metric": "host.lustre.stats.read.bytes",
     "dps": {
       "1515756295": 5104980744214,
       "1515756305": 5104980753366,
       "1515756310": 5104980867566,
       "1515756290": 5104980741946,
       "1515756300": 5104980753366
     },
     "aggregateTags": [],
     "tags": {
       "name": "lustre01",
       "system": "mistral",
       "host": "m10753"
     }
   }
 ]
}
```

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General Information about the Test Dataset

- Data from 5 day (from 2018-12-07 to 2018-12-13)
- 70846 jobs statistics downloaded in JSON format (360GB)
- **33193 (47%) jobs are evaluated**, that
  - contain non-empty time series and
  - and have exit status `COMPLETED`
- 203 users $\rightarrow$ 183 jobs per user in average

Exit status statistics

1026	CANCELLED
63636	COMPLETED
5753	FAILED
3	NODE_FAIL
426	TIMEOUT

Derived Metrics

- New metrics
  - that **provide more information**
  - e.g. "bytes/call" for read and write
- Other job characteristic metrics
  - to **identify I/O intensive jobs**
  - e.g. data read and written by a node
- Independent metrics
  - that can be used to **compare jobs**
  - e.g. average call rate done by a process

Examples: write metrics

metric	Description
'write_bytes'	Data written (job)
'write_bytes_nn'	Data written (node)
'write_bytes_ppn'	Data written (process)
'write_bytes_rate'	I/O performance (job)
'write_bytes_nn_rate'	I/O performance (node)
'write_bytes_ppn_rate'	I/O performance (process)

Example: Statistics for an I/O intense Job

General information

Nodes	4
Processes	7
Elapsed time	4.8h

Metadata access

Metadata read ops	27 Mops
Metadata read frequency	**1537 ops/s**

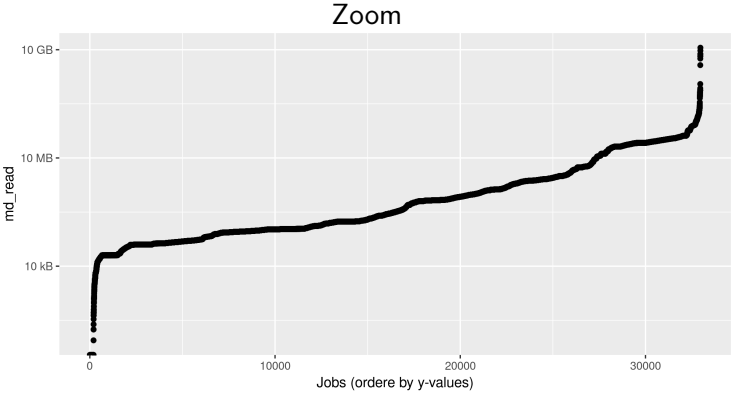
Read

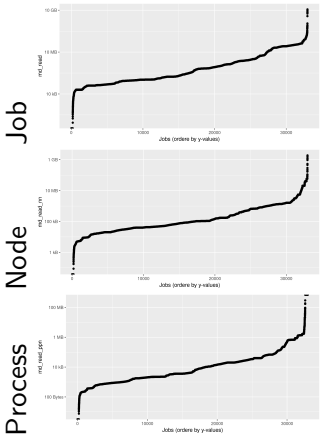
(Avg.) Bytes/op	**4 MB**
Total data	78 TB
(Avg.) Performance (job)	4.5 GB/s
(Avg.) Performance (node)	**1.1 GB/s**
(Avg.) Performance (process)	0.2 GB/s
Operations	19.3 Mops
(Avg.) Operation frequency	1108 ops/s

Write

(Avg.) Bytes/op	**3.3 MB**
Total data	71 TB
(Avg.) Performance (job)	4.1 GB/s
(Avg.) Performance (node)	**1.0 GB/s**
(Avg.) Performance (process)	0.1 GB/s
Operations	21.2 Mops
(Avg.) Operation frequency	1218 ops/s

Looking at Metadata





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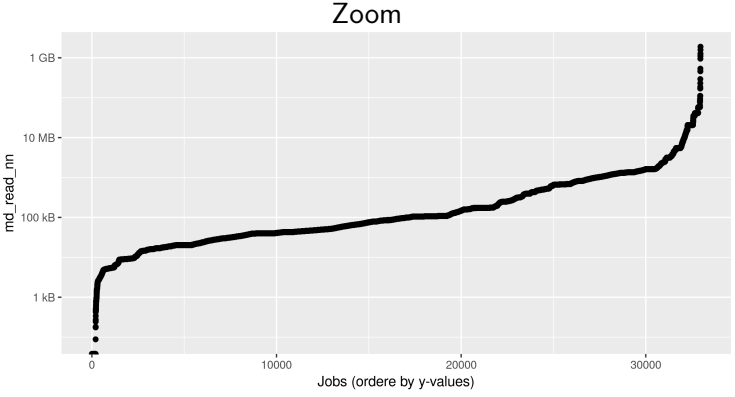

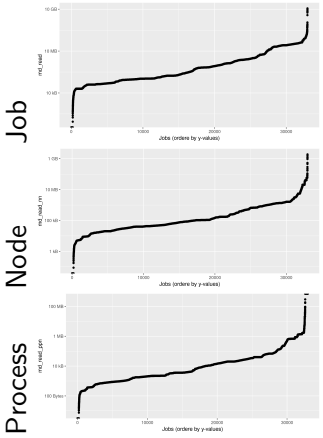

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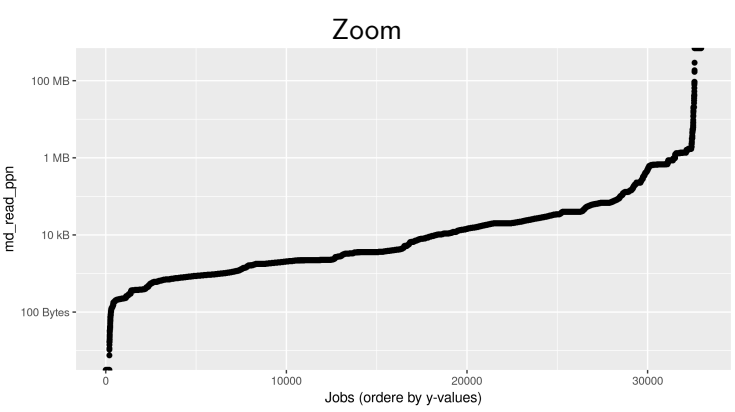

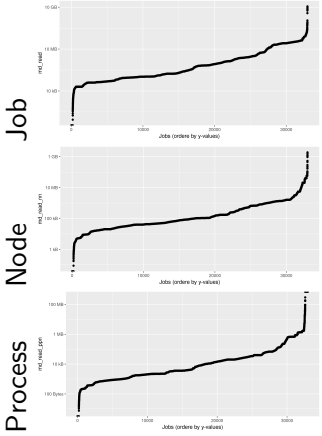

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md_read = getattr + getxattr + readdir + statfs + listxattr + open + close
```

Example of Ranking Across Jobs and Users

Who are the top 5 jobs and users, doing the most meta data reads?

Jobs

jobid	md_read Millions	job_name	username
144U	11,371	fw	u2
144V	9,475	fw	u2
144X	7,583	fw	u2
144Y	7,579	fw	u2
144Z	6,640	fw	u2

Users

username	md_read / job Millions
u2	5094
b3	234
m3	187
a2	118
m2	106

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Summary

- DKRZ monitoring system
  - **Open source** components + self-developed collector
  - **Portable** to the next HPC and other machines
- Analysis approach
  - **Ranking** of metrics of interest
- First analysis allows us to identify
  - **Identify large workloads**
  - **Find users** who create large workloads
  - **Compare jobs**