HPS
https://hpc.gwdg.de

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MPI-based Creation and Benchmarking of a Dynamic Elasticsearch Cluster

1 Introduction

2 Spawner

3 Ingestor

4 Querier

5 Test Evaluation

6 Conclusion

Insights

- Why a custom spawner and new specialized benchmarker is required
- How the following works:
  - distributed cluster spawner
  - distributed ingestion benchmarker
  - distributed query benchmarker
- How to create a new benchmark scenario from scratch

Motivation: Data Lakes

Why are Data Lakes needed

- Research becomes evermore data-driven and compute-intensive
  - More Simulations
  - Data Science, Machine Learning
- HPC becomes more data oriented
- Better data-management tooling needed
- HPC operates on raw data
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Metadata management

- Providing storage is easy
- Managing storage is hard
- Keep data findable, manage data
- Fully indexed
- Fully (fuzzy) searchable
- No-SQL data store / search engine
  - Elasticsearch

Motivation: Elasticsearch and Rally

Elasticsearch for HPC

- Elasticsearch is designed for cloud-use
  - Always running
  - Same host, same IP
  - Only ethernet
- This is not given in HPC:
  - Jobs spawned on demand
  - Every job gets different nodes
  - Changing IPs between runs
  - ETH, IB, Intel OPA
- Thus, a custom **stateful** workflow is required for HPC use!

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Benchmarking Elasticsearch

- HPC is all about performance
- Elastic's benchmarker: *rally* [1]
  - Used for in-house performance regression testing
  - Written in Python
  - Distributed using *thespian* agent framework
  - After previous unpublished research at GWDG:
    - Doesn't work with over 60 nodes
- Not viable for HPC-scale benchmarking

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4. **Example workflow** for canonical dataset

Background: Elasticsearch

- Distributed search engine
- Document-based NoSQL-Storage
- Internally based on Apache Lucene
- Provides JSON-based REST interface
- Apache 2.0 fork: Opensearch
- Advantages:
  - Mature ecosystem
  - Very battle-tested
  - A lot of tooling / library support

Background: Benchmarking

- For elasticsearch: All literature uses rally [2] [3] [4]
- Alternatives: Just use a HTTP benchmarker
  - JMeter [5]
  - wrk [6]
  - Grafana k6 [7]
- Most NoSQL comparisons are done by database vendors [8]
  - Bad financial incentives

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  - on **different nodes**
  - **without reingestion**

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  - **without reingestion**
- NIC-agnostic. Tested on:
  - Ethernet
  - Infiniband

On-Demand, Dynamic Cluster Spawner (cont.)

High-Level Workflow:

Prerequisites:

- All hosts are known to each other via the MPI environment
- All nodes have at least one shared mount

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On-Demand, Dynamic Cluster Spawner (cont.)

Example Generated Config

```
cluster.name: securemetadata
node.name: securemetadata4
node.roles: ["master", "data"]
network.host: 0.0.0.0
cluster.initial_master_nodes: [securemetadata0]
# Expects hostnames to be DNS resolvable
discovery.seed_hosts: [
  "hostname_of_rank_0",
  "hostname_of_rank_1",
  "hostname_of_rank_2"
]
xpack.security.enabled: false
```

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- ☐ Query Benchmarker
- ☐ Example workflow for canonical dataset

Ingestion Benchmarker

- Two purposes:
  1. Ingest JSON corpus into Elasticsearch cluster for query benchmarks
  2. Measure performance of **write-performance** and throughput
- Features:
  - Distributed, MPI-based
  - I/O optimized through *offset caching*
  - Supports statically typed index definitions
  - Supports Newline Delimited JSON (NDJSON)
    - Thus compatible with rally!
  - Configurable via CLI: bulk size, shards per node

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- Steps:
  1. Read 1: Count number of lines.
  2. Compute starting and ending line for each rank.
  3. Read 2: Find the byte offsets for each rank.
  4. Save everything into a `.offsets.json` file.

Offset Caching (cont.)

Example `.offset.json` file for 3 nodes


```
{
  "number_of_workers":3,
  "offsets":[
    {
      "rank":0,
      "starting_line":0,
      "starting_byte":0,
      "number_of_lines":8333
    },
    { "rank":1, "starting_line":8333,
      "starting_byte":4157901, "number_of_lines":8333 },
    { "rank":2, "starting_line":16666,
      "starting_byte":8315734, "number_of_lines":null }
  ] }
```

Ingestion Benchmarker (cont.)

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- MPI Gather all data at root, dump into JSON file

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  - Test mode for easier debugging

Input Format for Query Benchmarker (part 1)

```
[
  {
    "search_queries": [
      {
        /* everything in here just gets sent to ES */
        "body": {
          /* The raw ES query sent to the server */
        }
      }
    ],
    "warmup_time_secs": 30, /* optional */
    "execution_time_secs": 120, /* optional */
  },
  ...
```

Input Format for Query Benchmarker (part 2)

```
{
  "search_queries": [
    {
      "body": {
        /* The first of 2 queries sent iteratively (random order) */
      }
    },
    {
      "body": {
        /* The second of 2 queries sent iteratively (random order) */
      }
    }
  ],
  "warmup_time_secs": 30, /* optional */
  "execution_time_secs": 180, /* optional */
  "sleep_between_requests_secs": 0.25 /* optional */
}]
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6. Run the distributed query benchmarker using the query document
7. Analyze the output JSON using a language of your choice
   Python example can be found in the Git repo.

Benchmark

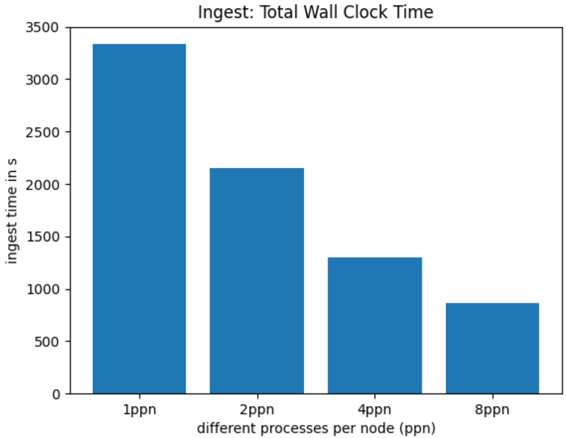
Dataset: NYC Taxis [9]

- All yellow taxi rides in NYC in 2015
- Published by NYC Taxi and Limousine Commision [10]
- 165 million documents, over 75GB
- Also used by Rally (Elastic)
- Most used for scaling testing
- Big documents, but mostly numeric data.

Setup

- 3 standard96 nodes on Emmy
- Ethernet
- Ubuntu 22.04 dockerhub image in Singularity
- Elasticsearch 8.11.0 with OpenJDK 21.0.1
- Python 3.9
- OpenMPI 4.1

Results



- Wall clock time decreases when increasing processes per node
- More ingestion parallelism increases performance
- But sublinear scaling
  - Less efficient per extra ingestor process

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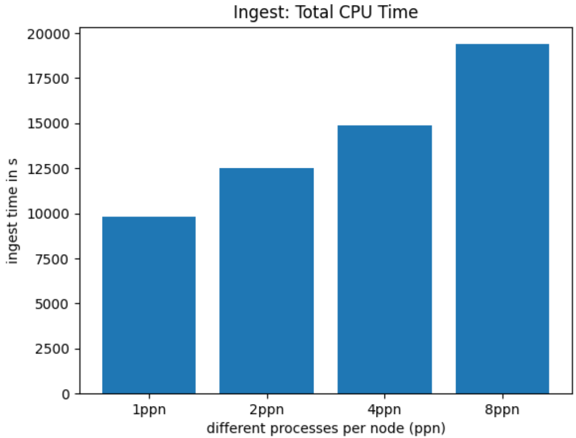

- CPU time:
  Wall clock · number of processes
- It becomes less CPU efficient with more ingestion nodes
- If linear scaling in last plot ⇒ the CPU ingestion time would stay the same

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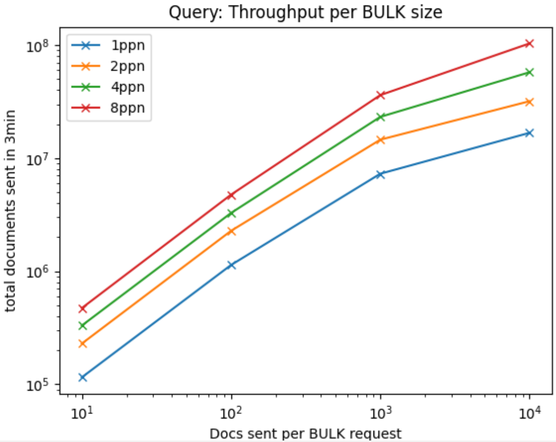
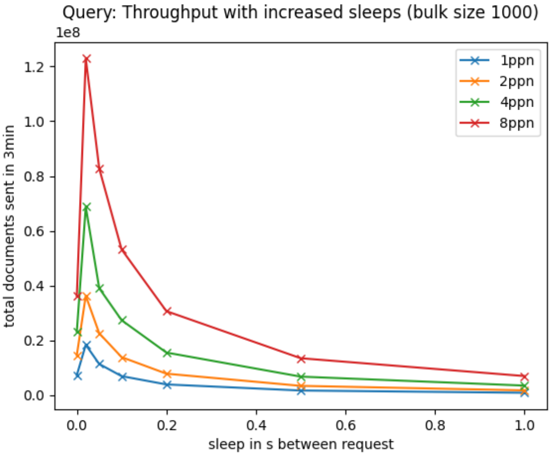


- Works as expected
- When sending more documents per request, the HTTP overhead should decrease
- This works for all ppn
- Increase becomes sublinear

Results



- Sleeping 0.02s is more efficient than not sleeping between requests!
- 0.2s is approximately as efficient as 0.0s.
- After that, it becomes less efficient since the Elasticsearch is idling.
- Possible explaination: Additive Increase, Multiplicative Decrease (AIMD) in TCP, see report

Challenges/Open Problems

- Limited response size, hard limit by Elasticsearch's architecture
- Not possible to map load generator to cluster node according to optimal network topology
- Load generators and clusters cant share the same node
- Elasticsearch requires a custom kernel setting

Summary

- Project was a success, fully implemented both workflow and benchmarker
- Zero configuration needed once the benchmark was initially designed
- Fully integrated into SLURM
- Contributions:
  1. On-demand Elasticsearch Cluster Spawner
  2. Ingestion Benchmarker
  3. Query Benchmarker
  4. Example workflow for canonical dataset

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