HPS
https://hpc.gwdg.de

Lars Quentin

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
  $\Rightarrow$ Data Lakes

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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  - After previous unpublished research at GWDG: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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   - Custom scenario support using own JSON-based DSL
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

On-Demand, Dynamic Cluster Spawner

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

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- 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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See the accompanying report for a more low-level workflow.

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
```

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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4. Spawn up the cluster using SLURMs MPI environment
5. Run the distributed ingestor to ingest the NDJSON corpus
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

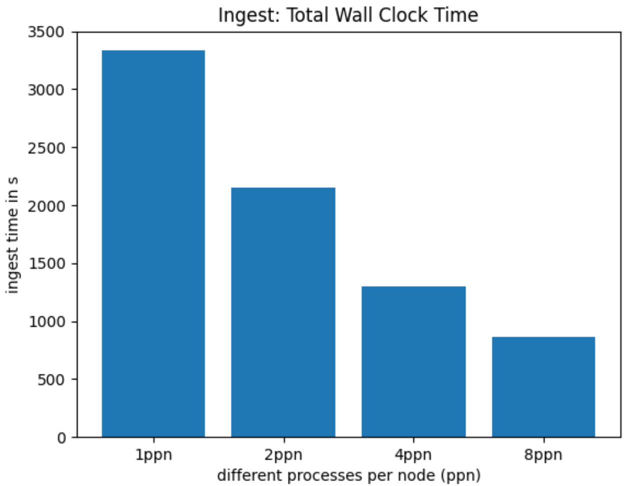
Dataset: NYC Taxis [9]

- 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 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


Ingest: Total Wall Clock Time
ingest time in s
3500
3000
2500
2000
1500
1000
500
0
1ppn
2ppn
4ppn
8ppn
different processes per node (ppn)

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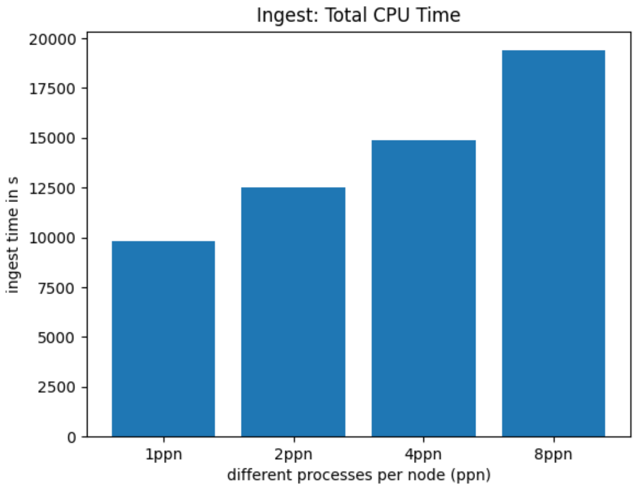
Ingest: Total CPU Time
ingest time in s
20000
17500
15000
12500
10000
7500
5000
2500
0
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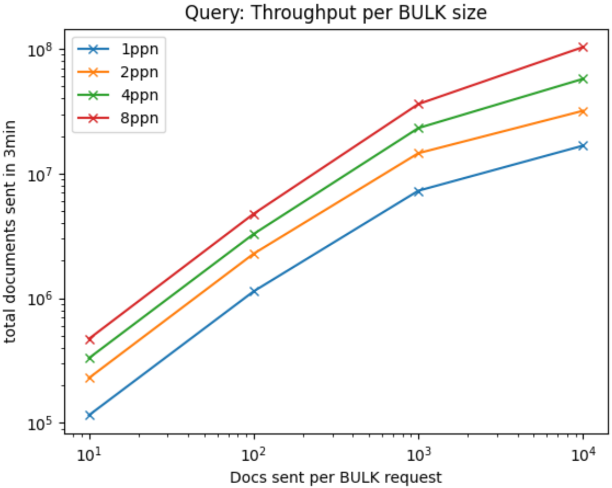
Query: Throughput per BULK size
1ppn
2ppn
4ppn
8ppn
10^8
10^7
10^6
10^5
total documents sent in 3min
10^1
10^2
10^3
10^4
Docs sent per BULK request

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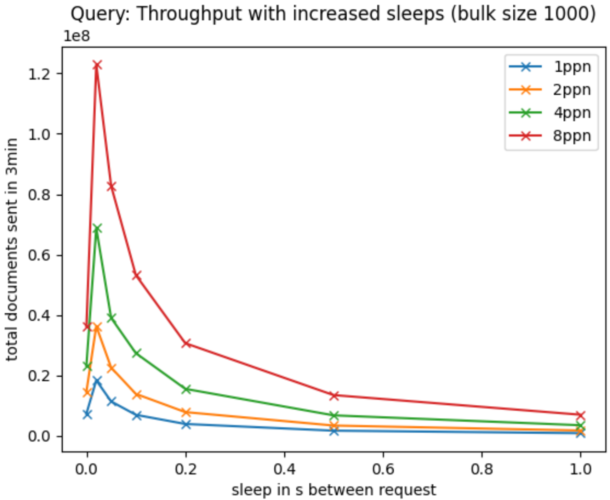
Query: Throughput with increased sleeps (bulk size 1000)
1e8
total documents sent in 3min
sleep in s between request
1ppn
2ppn
4ppn
8ppn
0.0
0.2
0.4
0.6
0.8
1.0
1.2

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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