Seven Deadly Sins of Elasticsearch Benchmarking

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What is Benchmarking?

Characteristics

- **Run** a well-defined workload
- **Measure** performance metrics
- **Change** a parameter
- **Compare** results

Sin One

Ignore System Setup

Relevancy

Be close to production

- **Same hardware**: CPU, memory, disk, network
- **Same software**: kernel / system libraries, JVM and Elasticsearch version
- **Same configuration**: file system, I/O scheduler, network configuration

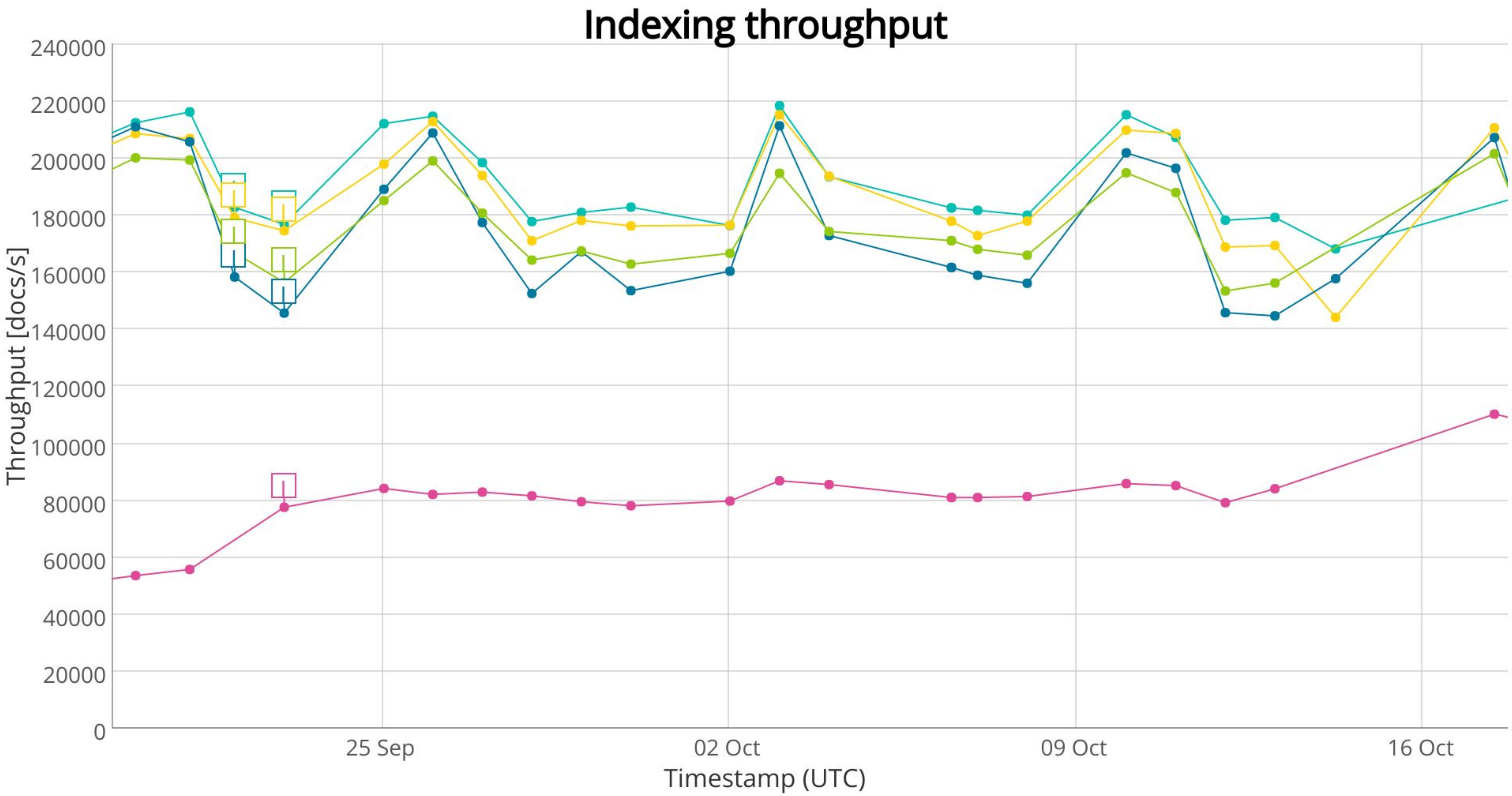
Reduce Noise

Better reproducible numbers

- Stable environment: Don’t change kernel / system libraries, JVM and Elasticsearch version
- Turn off system daemons (e.g. updates)
- Load generator is on a separate machine
- Low-latency, high-throughput network between all machines
- No other traffic on that network

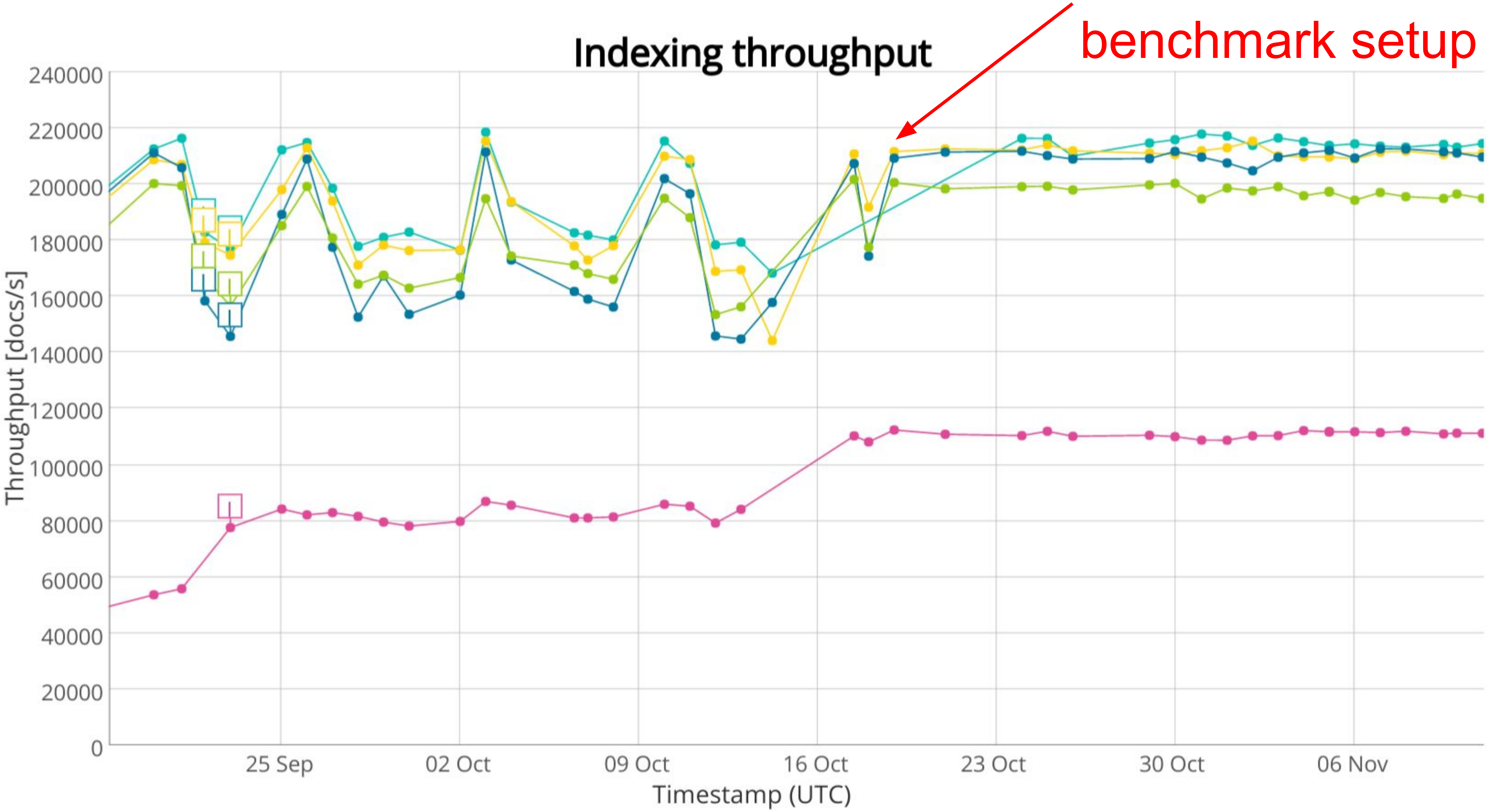
Reduce Noise

Weekly variation in throughput?



Reduce Noise

TRIM your SSD drive



TRIM enabled in benchmark setup

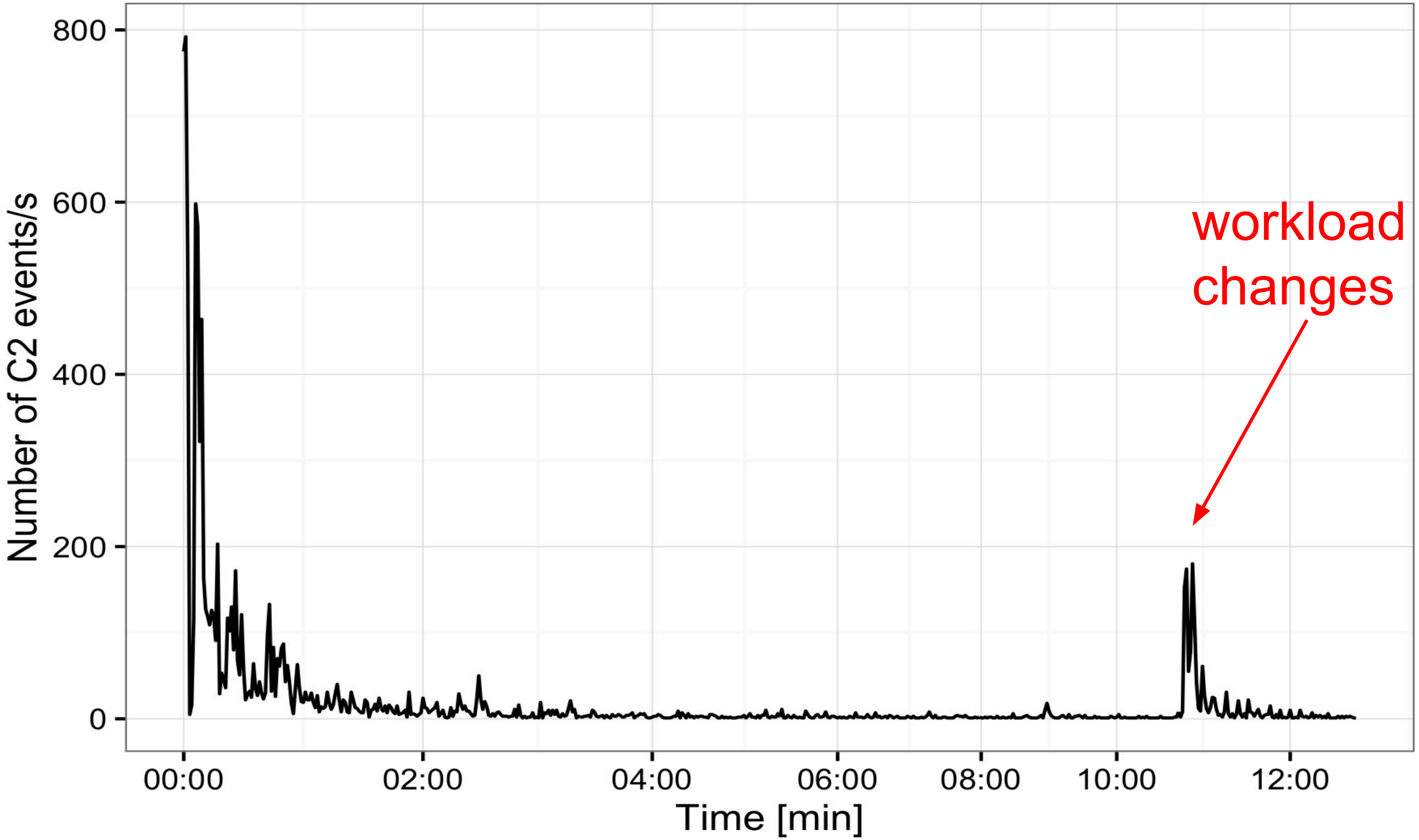
Sin Two

Cold Start

Are you awake before your first coffee?

Warmup Effects

JIT Compilation



workload changes

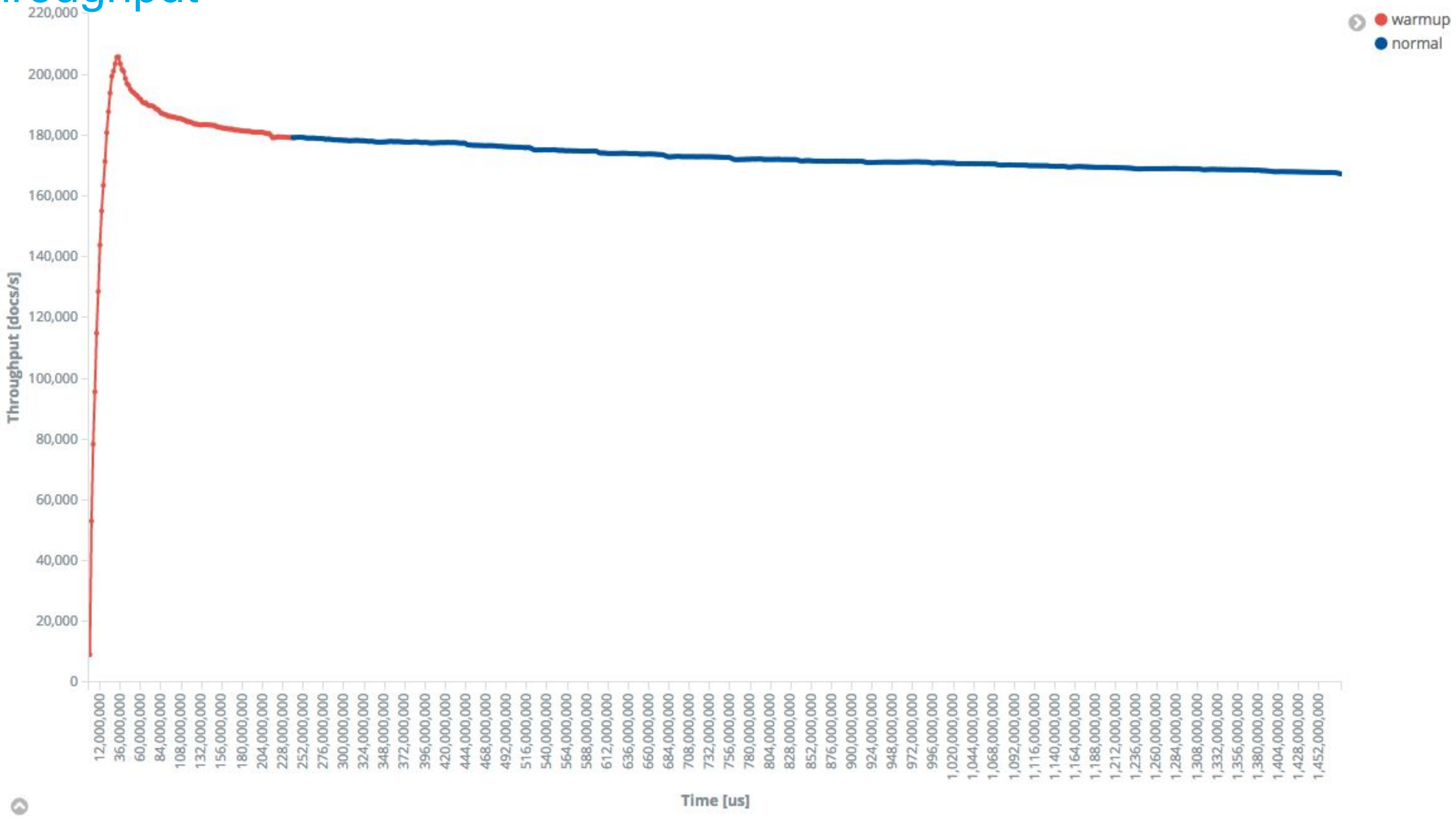
Caches Everywhere

Consider in Warmup and Workload Definition

- **CPU** L1 - L3 cache (incl. prefetching unit)
- **Disk**-internal cache (absorb I/O spikes)
- **OS** page cache (buffers writes to disk)
- **Application** caches: shard request cache, node query cache

Warmup Effects

Indexing Throughput



Sin Three

Hit it as hard as possible

Waiting Time

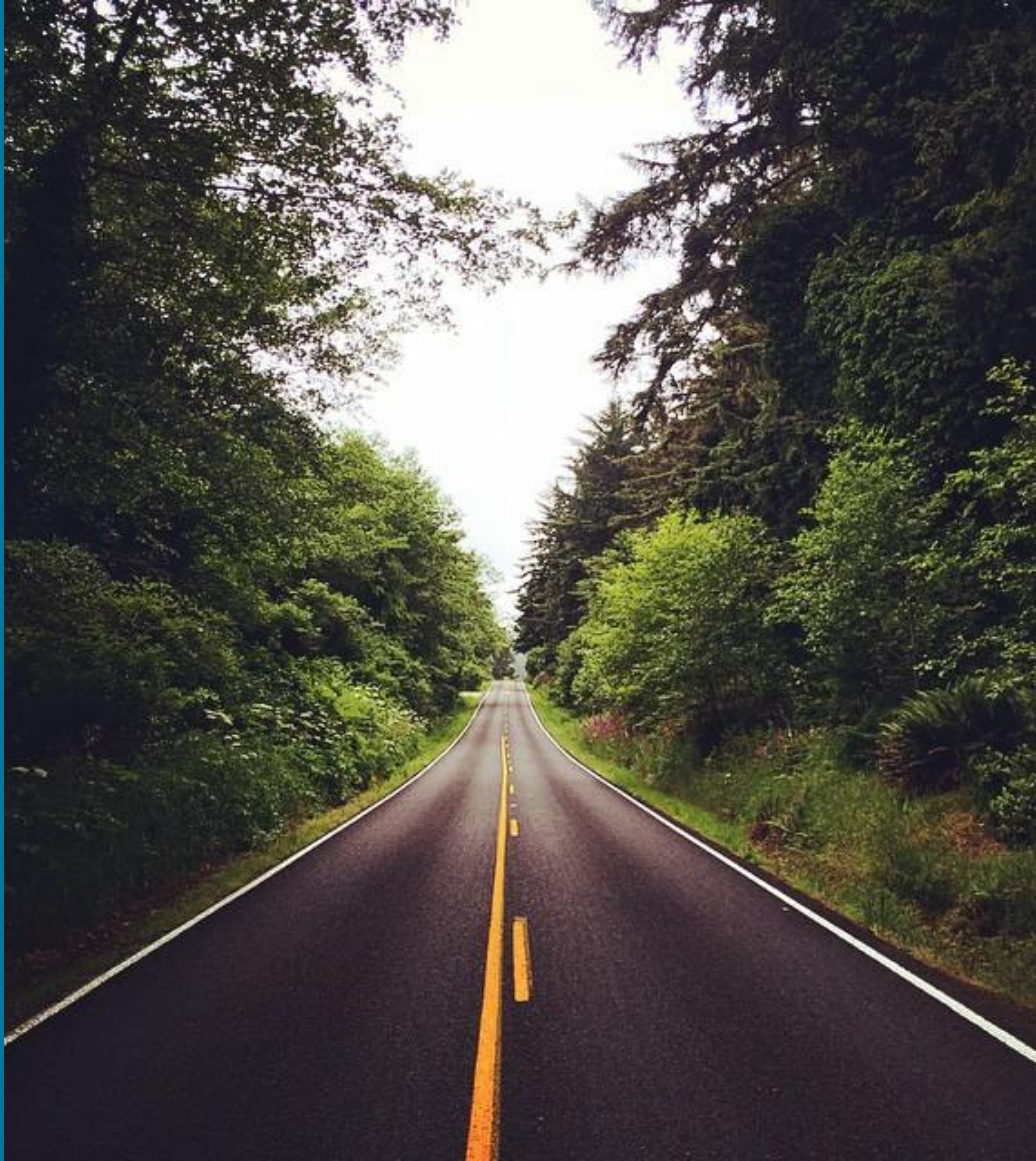
Starbucks Reserve Coffees
Exotic, rare and exquisite
Individually brewed on the Clover
100% Kona 2.25 2.45
Nicaragua Diamond 2.25 2.45
100% Oahu 2.25 2.45
Jamaica Blue Mountain 2.65 2.85
The new standard perfectio
Yours.

Service Time

Latency = Waiting Time + Service Time

Utilisation

At 0%: no waiting time



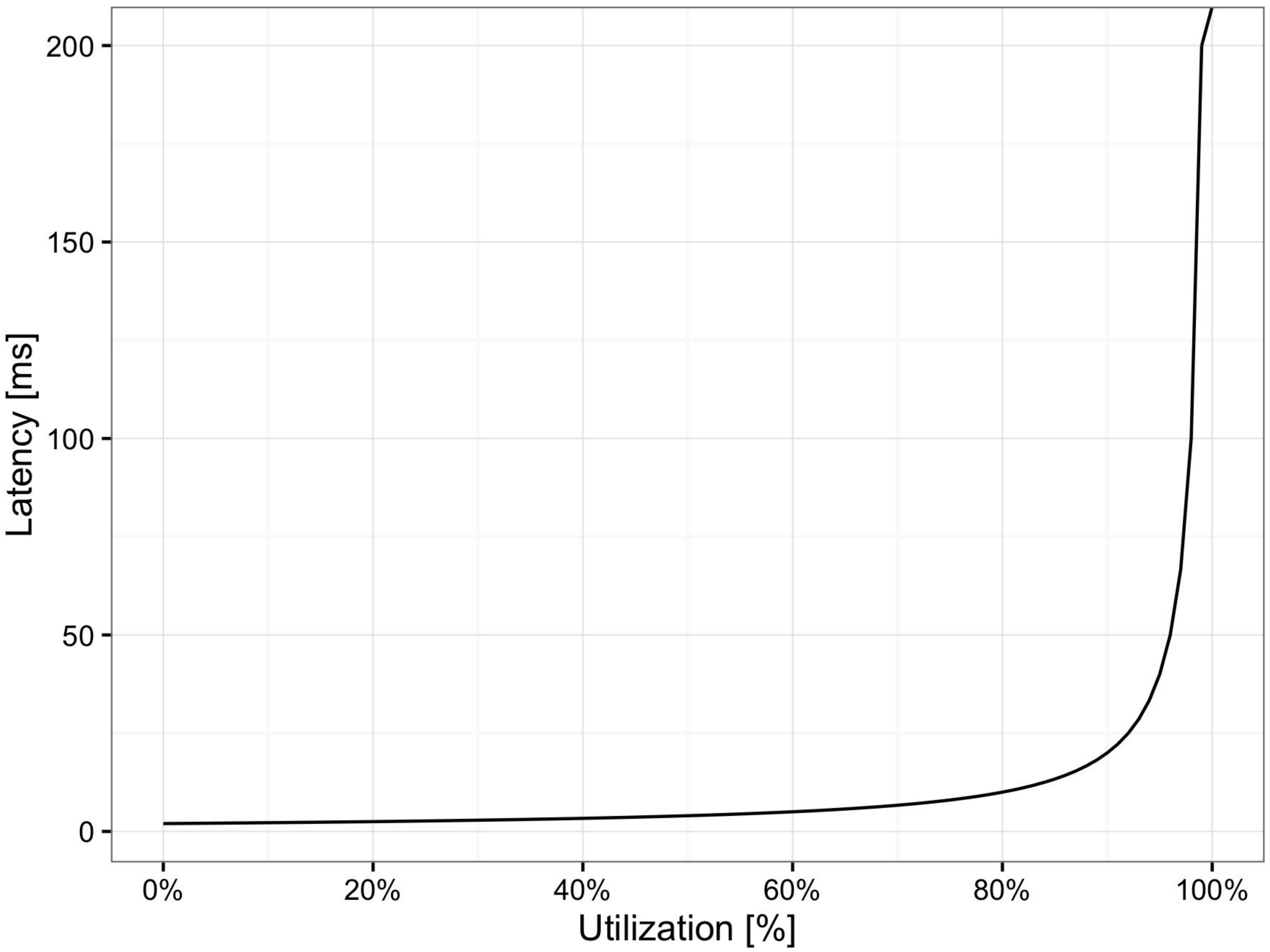
Utilisation

At 100%: high waiting time

Throughput and Utilisation

Latency...

… but at which throughput?



Created based on http://robharrop.github.io/maths/performance/2016/02/20/service-latency-and-utilisation.html

Tips

Batch Operations (e.g. bulk indexing)

- Important metrics: Throughput
- Run at maximum throughput
- Watch error rate (bulk rejections, request timeouts) and reduce load if necessary

Tips

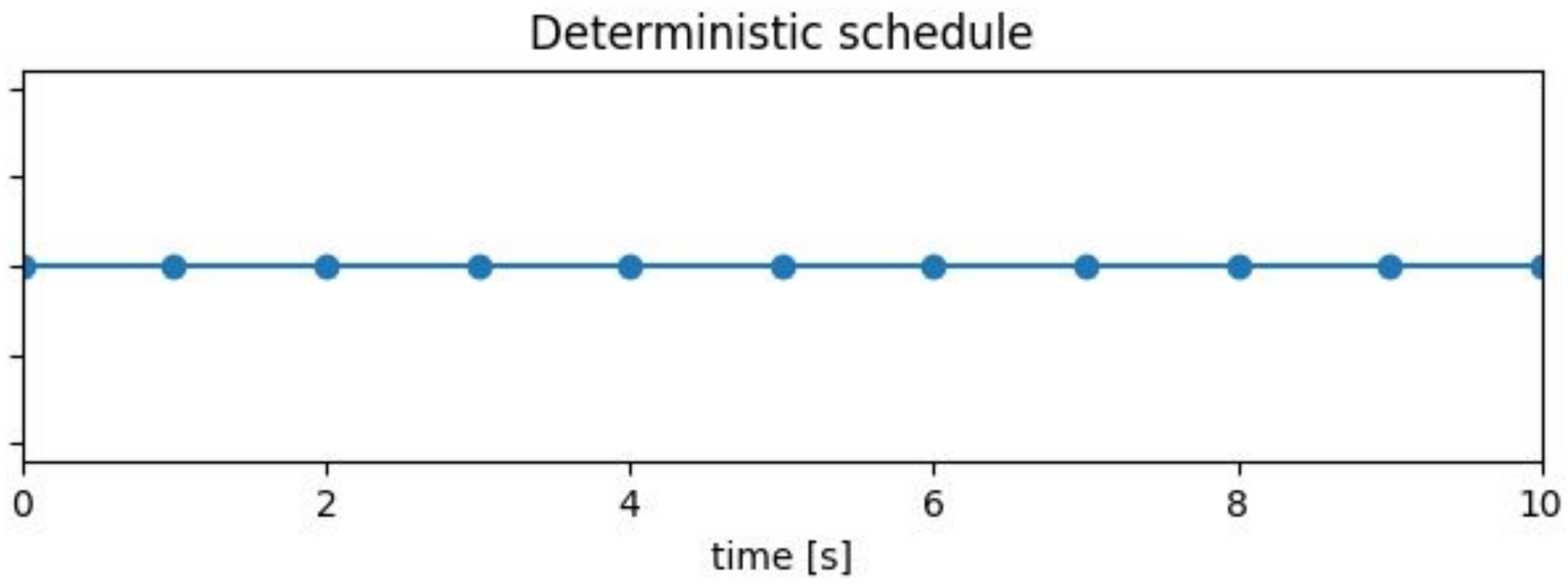
Interactive Operations (e.g. searches)

- Important metrics: Latency
- Run at a defined throughput (use production metrics for guidance)
- Latency >> service time is a clear sign of saturation

Measuring Latency

Modelling Arrivals: Deterministic schedule at 1 query/s

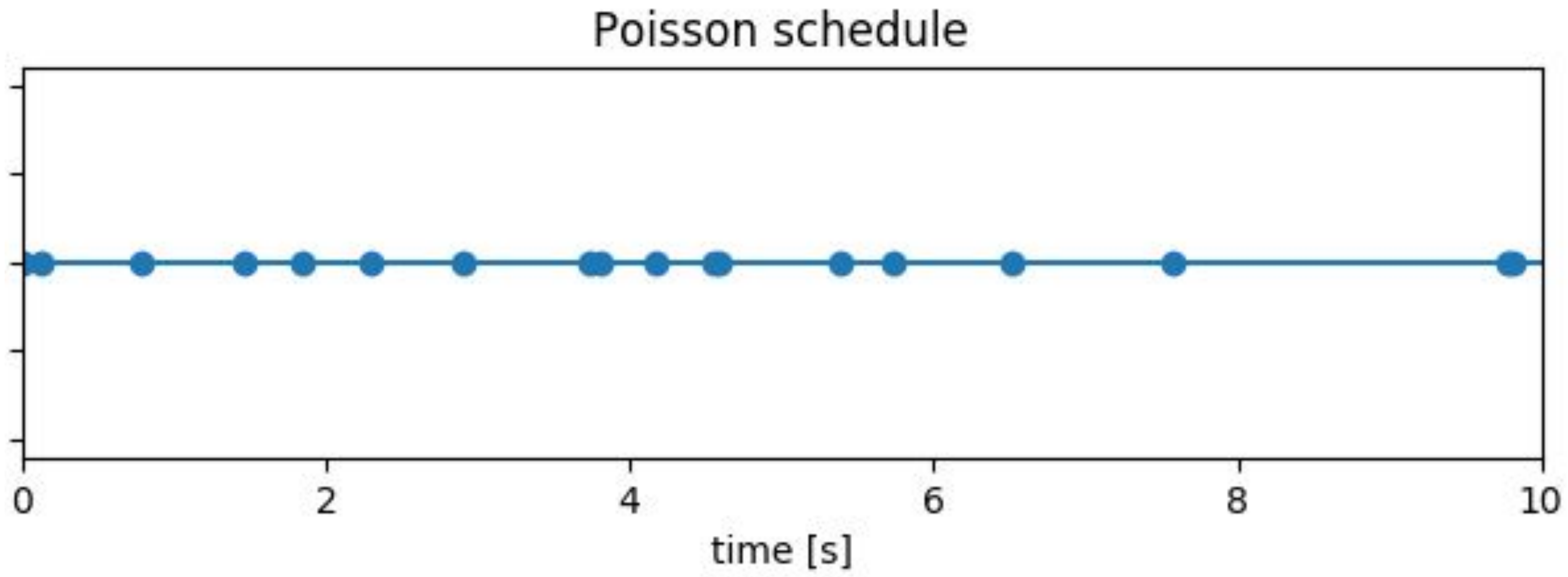
- Simple to understand
- Unrealistic for many scenarios (would require **coordination between users**)
- Tends to produce latency spikes with many clients (requests pile up)



Measuring Latency

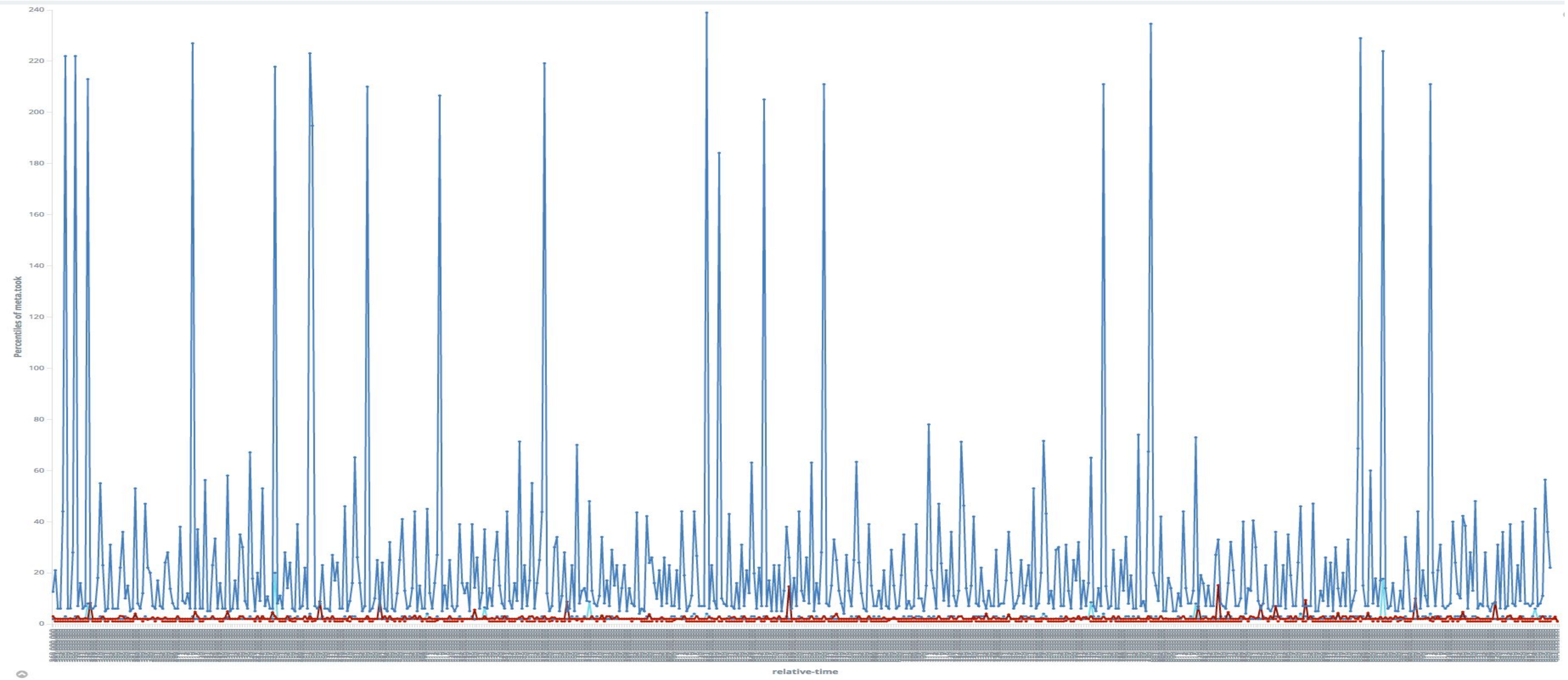
Modelling Arrivals: Poisson schedule at 1 query/s

- Probabilistic: not intuitive at first
- Often more realistic (models **independent users**)



Measuring Latency

Deterministic (blue) vs. Poisson (red) with 300 concurrent clients



Sin Four

The Divine Benchmarking Script

Newsflash: Benchmarking software has bugs

“It must be correct. After all, it produces numbers with 6 decimal places!”

- Response status code checks (the fast 404)?
- Maximum throughput of your load generator?

Example 1: Inappropriate Timeout

Overwhelming Elasticsearch

```
es = Elasticsearch(target_hosts)
while True:
    sendBulk(es)
```

Example 1: Inappropriate Timeout

Overwhelming Elasticsearch

```
# increase default request timeout
es = Elasticsearch(target_hosts, timeout=60)
while True:
    sendBulk(es)
```

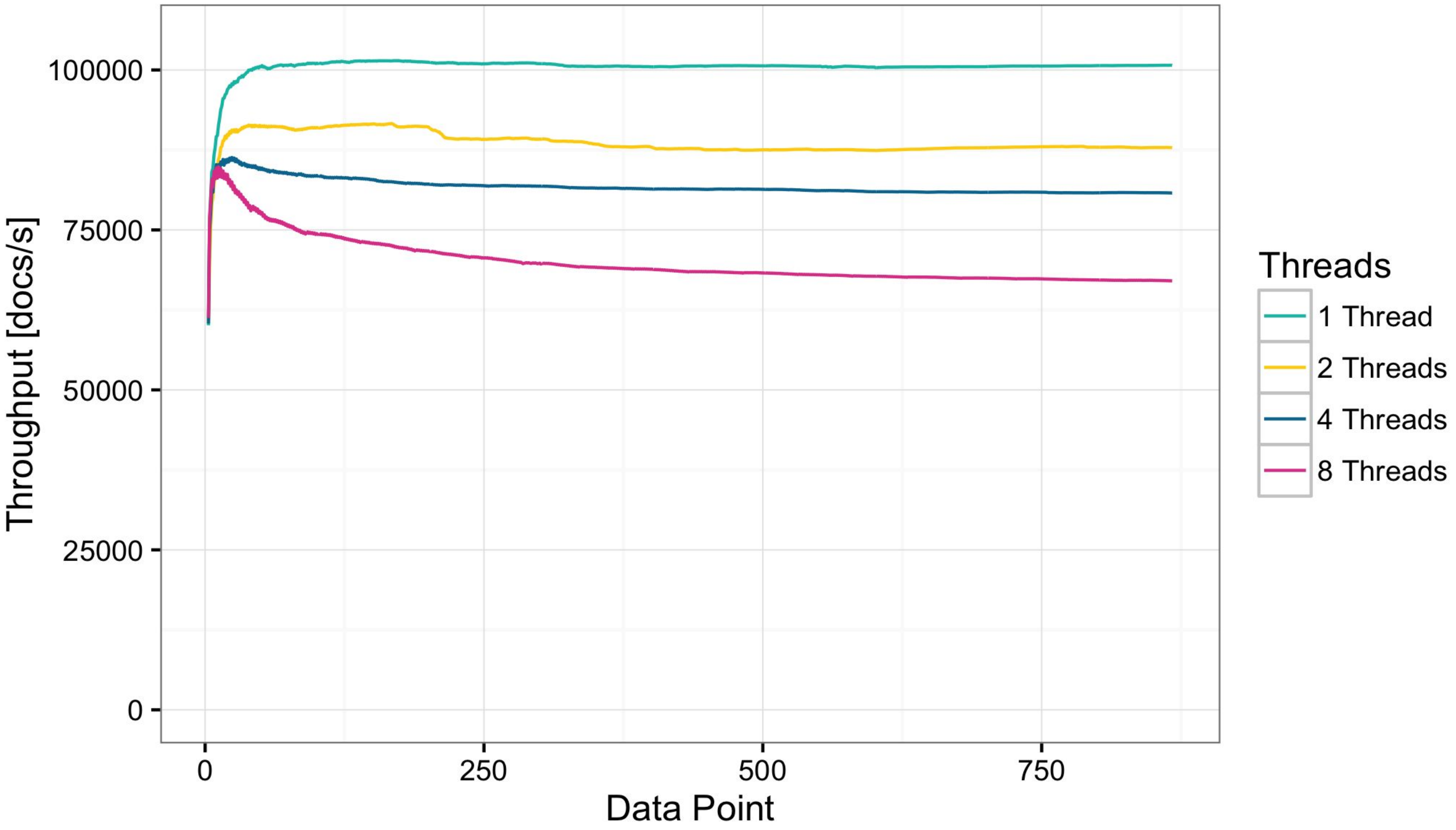
Example 2: Contention in Elasticsearch?

More clients, less load?

Client Count	Median Throughput [docs/s]
1	100.000
2	87.500
4	80.000
8	70.000

Example 2: Contention in the Load Generator!

More clients, less load?



Example 3: Let’s query

```
while read -r query
do
    curl --data "${query}" "http://es:9200/cars/_search" &
done < popular_car_queries.txt
```

Be critical

Check, check and then check again

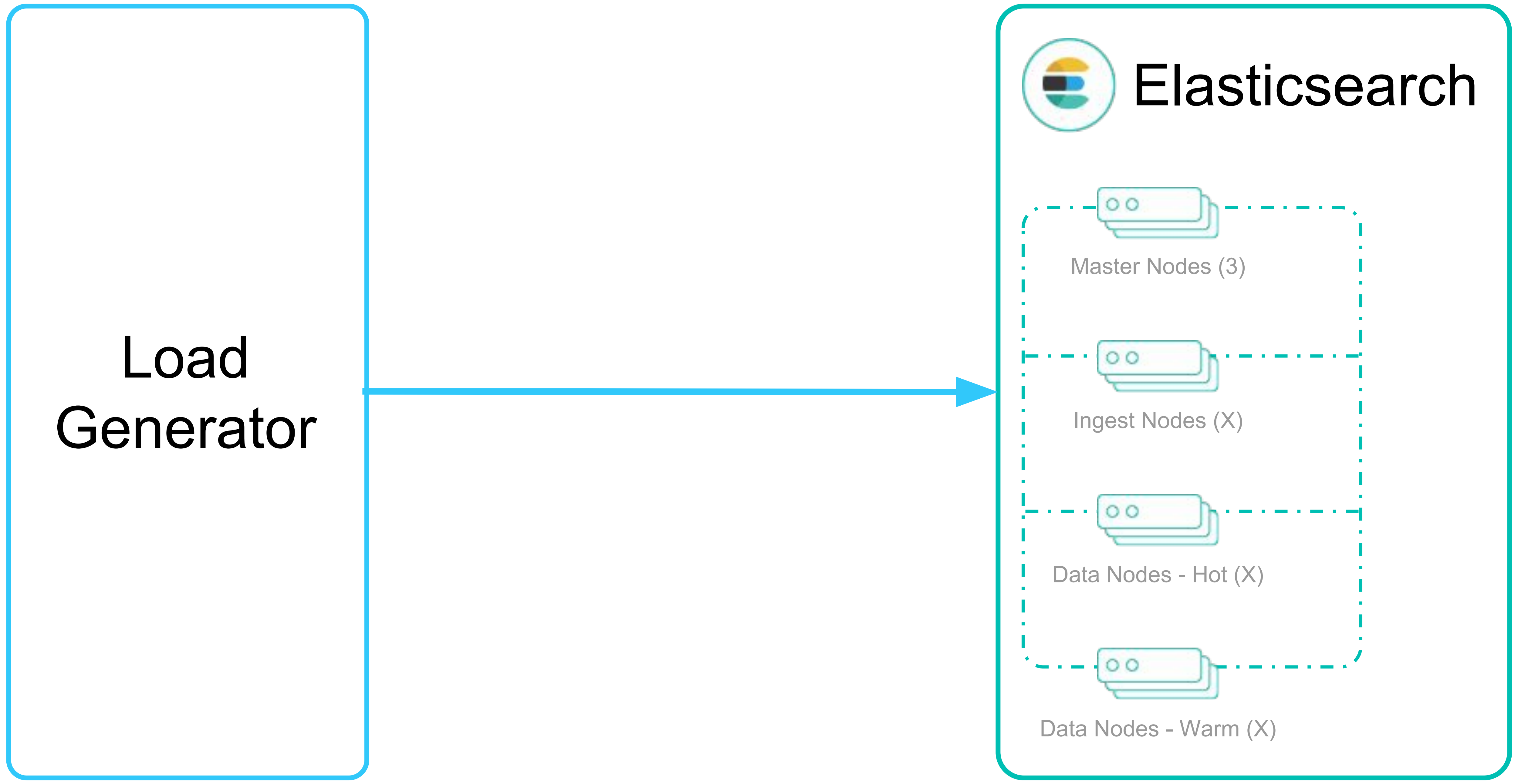
- Don’t trust any random script
- Stress-test your load generator
- Cross-check behavior on network level (Wireshark)
- Test error scenarios (e.g. 404s)

Sin Five

Unnoticed accidental bottlenecks

Are you stressing the right component?

Check every subcomponent



Are you stressing the right component?

More nodes: No throughput gains?

Elasticsearch Node Count	Median Throughput [docs/s]
1	1.300
2	2.600
3	2.600

Are you stressing the right component?

Example: Check network bandwidth with `ifstat`

```
  Time           ens3
HH:MM:SS   KB/s in  KB/s out
10:07:12      0.11      0.21
10:07:13     34.71  45218.57
10:07:14    224.08  91764.32
10:07:15    821.85  127922.0
10:07:16   1612.70  127817.9
```

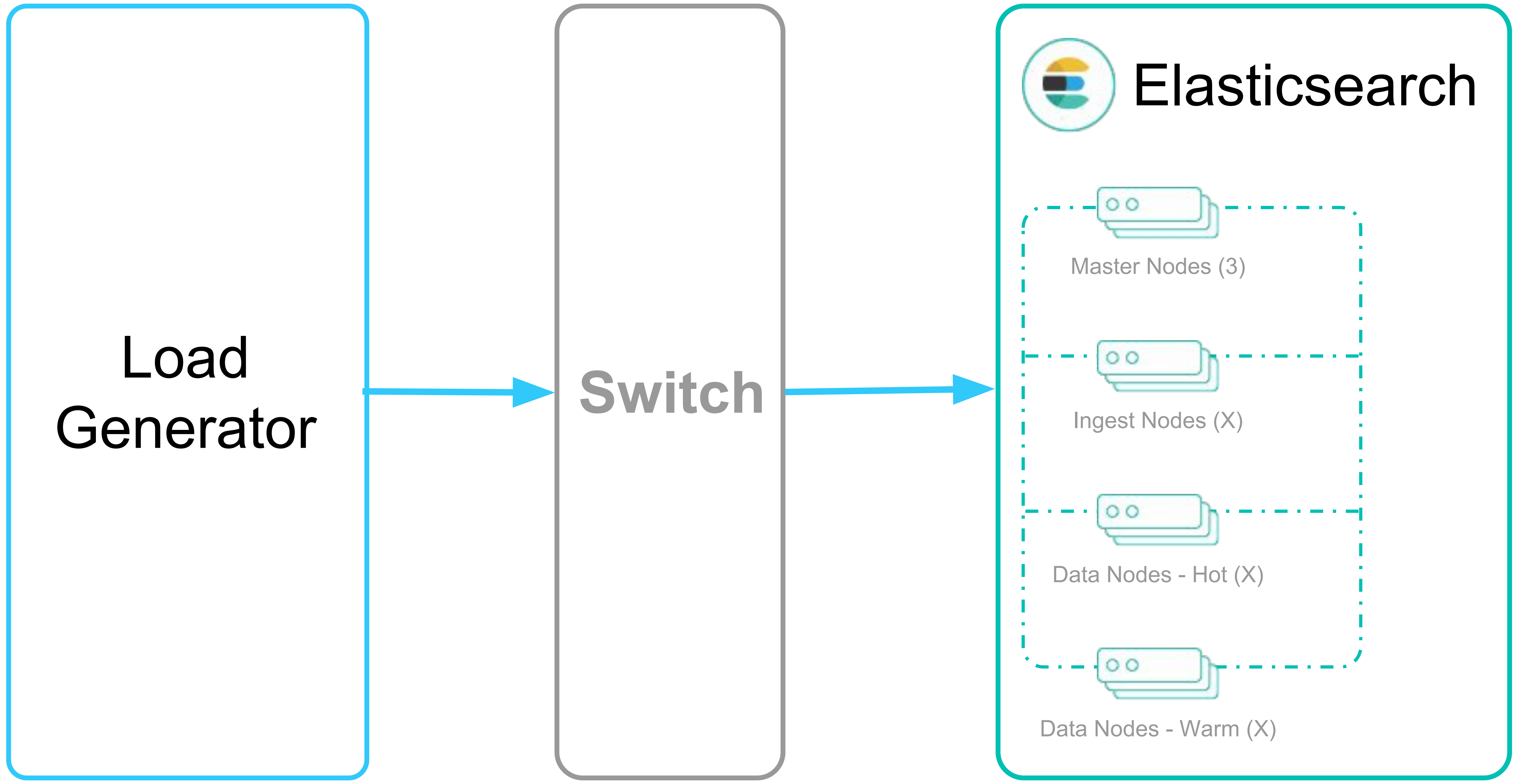
Are you stressing the right component?

Retry with a 10 Gbit card

```
  Time            ens3
HH:MM:SS   KB/s in  KB/s out
12:16:32      0.13      0.32
12:16:33     45.81  47114.57
12:16:34    354.18  96889.94
12:16:35    751.95  193469.0 # 1 Gbit link would be saturated
12:16:36   1722.80  271688.9
```

Are you stressing the right component?

Check **every** subcomponent



Are you stressing the right component?

Check methodically

- Example approach: USE method by Brendan Gregg (http://www.brendangregg.com/usemethod.html)
  - **U**tilization
  - **S**aturation
  - **E**rrors

Sin Six

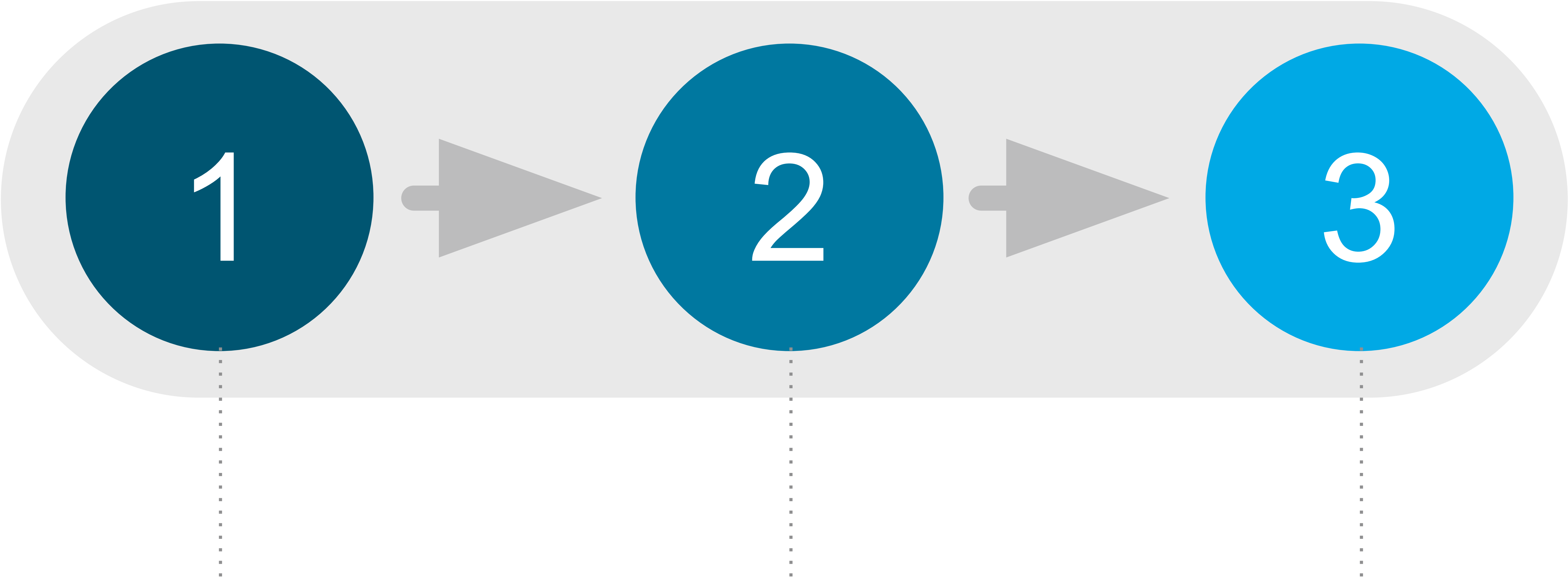
Chaos

I’ll update Elasticsearch …
… and the Java version.

A recipe for disaster

One Step at a Time

Benchmark Experiment Execution



Reset environment to known stable state

Change **one** variable

Run experiment (one or more iterations)

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What did I do to get these results?

Document Everything

Example metrics record

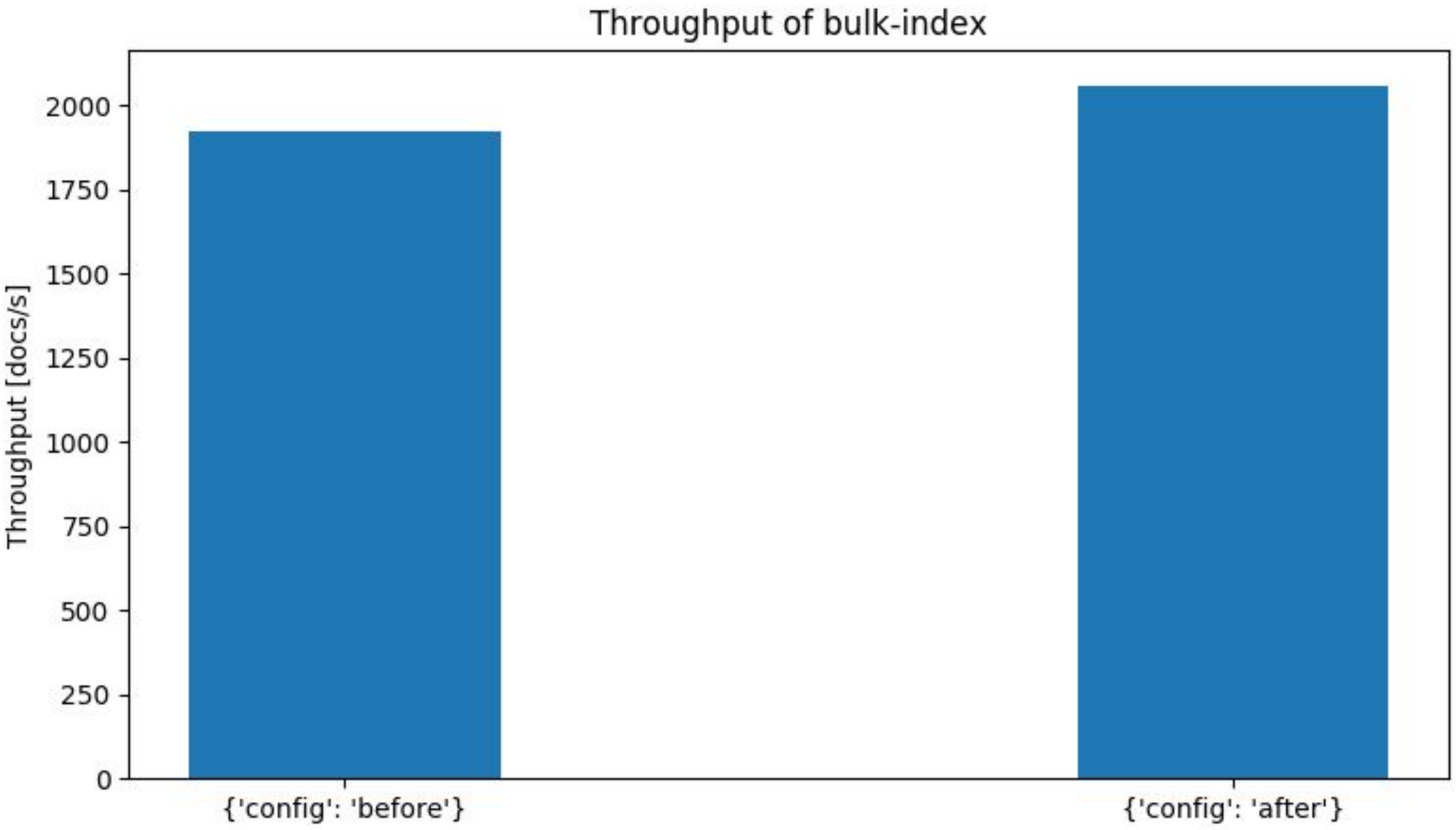
```
{
  "environment": "nightly",
  "trial-timestamp": "20180201T210054Z",
  "@timestamp": 1517544210265,
  "name": "cpu_utilization_1s",
  "value": 799.4,
  "unit": "%",
  "sample-type": "normal",
  "track": "nyc_taxis",
  "car": "4gheap",
  "meta": {
    "distribution_version": "7.0.0-alpha1",
    "source_revision": "df1c696",
    "node_name": "rally-node-0",
    "host_name": "192.168.14.3",
    "cpu_model": "Intel(R) Core(TM) i7-7700 CPU @ 3.60GHz",
    "os_name": "Linux",
    "os_version": "4.10.0-42-generic",
    "jvm_vendor": "Oracle Corporation",
    "jvm_version": "1.8.0_131"
  }
}
```

Sin Seven

Denying Statistics

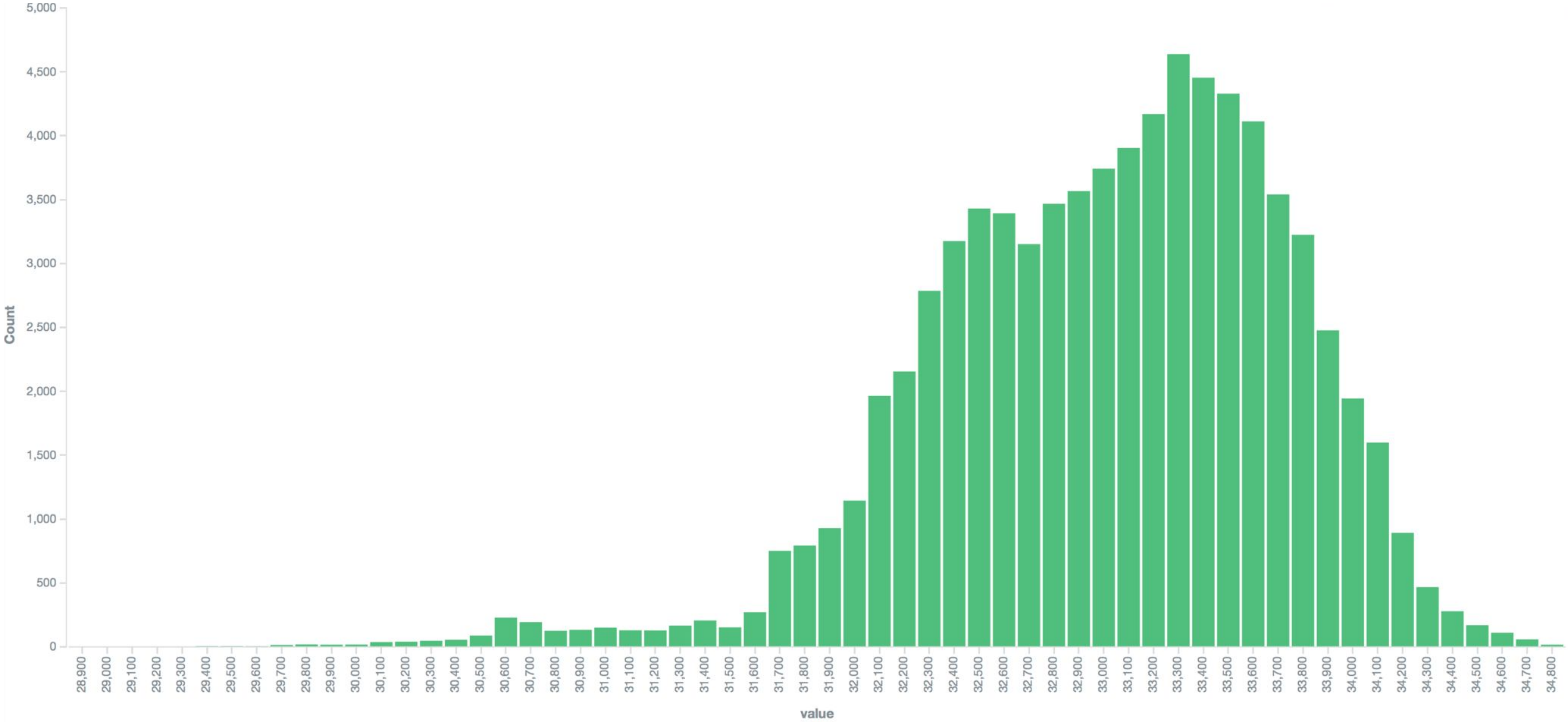
Our Benchmark Results

Are we done yet?



Example: Indexing Throughput Distribution

Lots of trial runs in identical conditions



Mitigating run-to-run variation

Statistical Significance Tests

- Control every variable that you can (see “reducing noise”)
- Run-to-run variation is a fact: lots of moving parts
- Multiple trial runs (> 30) and statistical significance tests (e.g. t-test)

Summarizing Results

General Tips

- Median, mean, mode: So many possibilities to choose! Median is robust against outliers
- Report also at least minimum and maximum so readers get a feeling of the degree of variance

Summarizing Results

Latency

- The meaningless mean: Half of the samples are **worse** than the mean. Use percentiles.
- False accuracy: Cannot calculate a 99.99th percentile from 10 samples
- Don’t assume normal distribution: latency is usually multi-modal (fast path / slow path)

Summary & Outlook

Ben is happy

1. Benchmarks run in production-like environment
2. Warmup is considered
3. Workload modelled correctly
4. Load test driver checked
5. No accidental bottlenecks
6. Structured benchmarking process
7. Results are checked for statistical significance

How do we benchmark at Elastic?

- Macrobenchmarking tool Rally: https://github.com/elastic/rally
- Rally implements many best practices that we covered in this talk
- Everything is open source: Tooling and data
- Everything is public: system configuration and detailed results

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> *Fall Seven Times, Stand Up Eight.*

Japanese Proverb

Questions?

AMA Booth
or
Birds of a Feather
(starting 3:30 pm)

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www.elastic.co

Reference Material

Further Reading

- Sin 1: On issuing TRIM: https://www.elastic.co/blog/is-your-elasticsearch-trimmed
- Sin 3: “Relating Service Utilization to Latency” by Rob Harrop:

  http://robharrop.github.io/maths/performance/2016/02/20/service-latency-and-utilisation.html
- Sin 3: “The Queueing Knee” by Baron Schwartz: https://www.xaprb.com/blog/queueing-knee-tangent/
- Sin 5: USE Method by Brendan Gregg: http://www.brendangregg.com/usemethod.html
- Sin 7: How not to measure latency by Gil Tene: https://www.youtube.com/watch?v=lJ8ydIuPFeU

Reference Material

Image Credits 1/2

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Reference Material

Image Credits 2/2

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