Crimson Performance: 56 weeks later

On becoming a Jack of all trades

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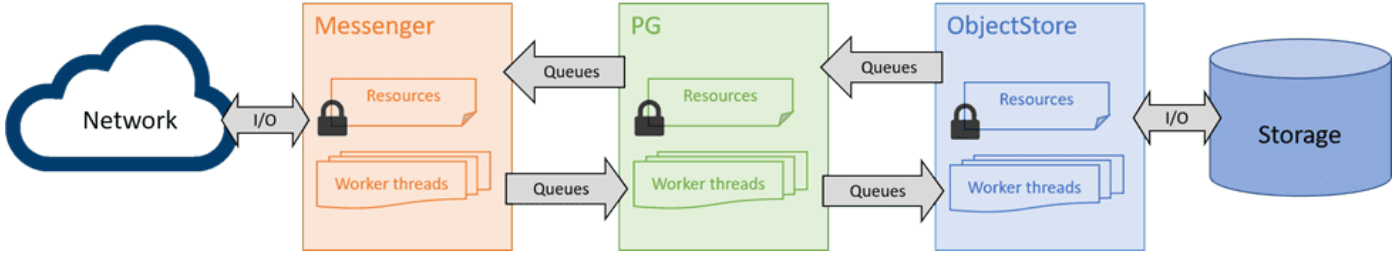
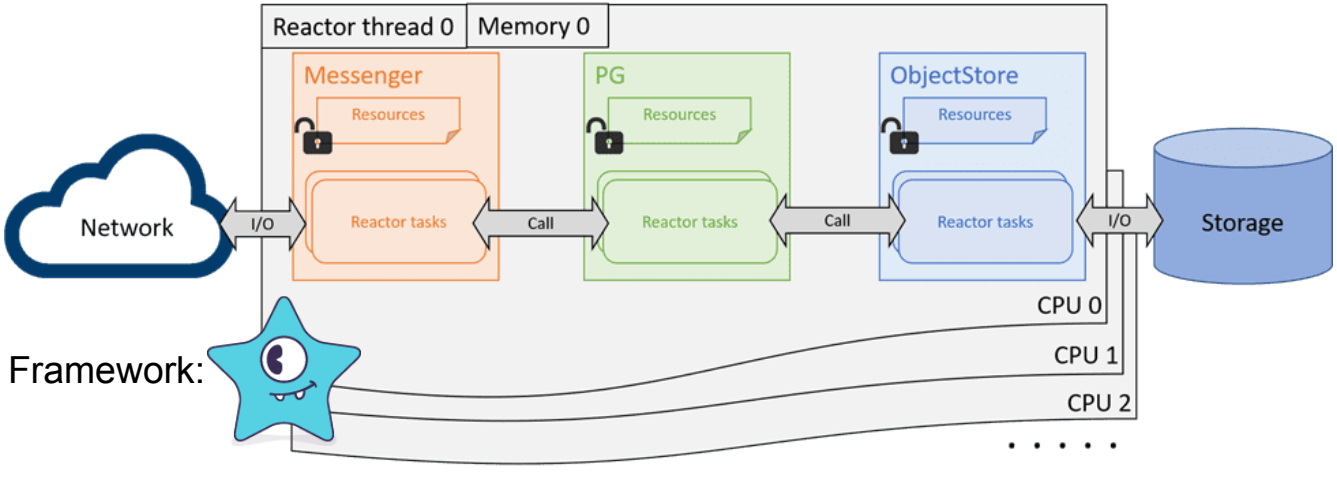
Crimson: reactor (share nothing) OSD architecture

Classic:



Crimson:



Seastar Framework:

Crimson: reactor (share nothing) OSD architecture

Crimson is engineered to be a high-performance Object Storage Daemon (OSD) optimized for fast storage devices such as NVMe

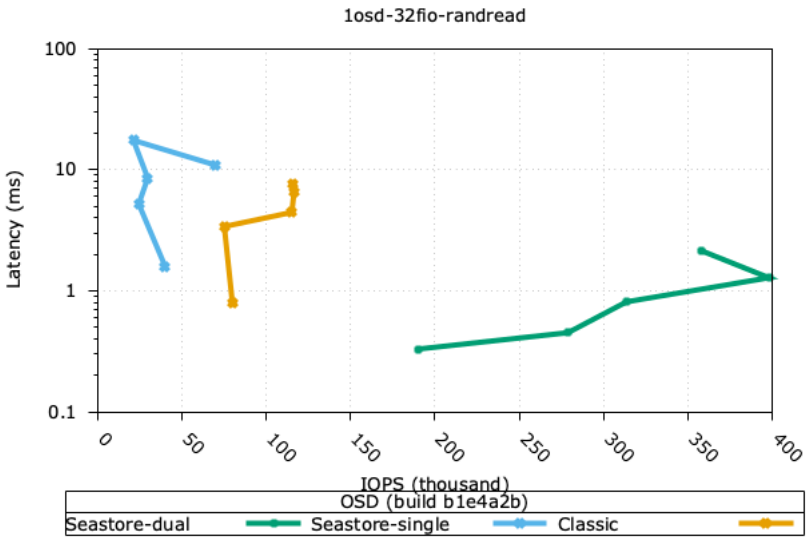
- **Kernel Bypass:** Direct communication with networking and storage devices that support polling, eliminating the overhead of kernel involvement.
- **Shared-Nothing Architecture:** Minimizes lock contention, ensuring smoother operation and higher performance.
- **Computational Efficiency:** Balances load across multi-core systems, enabling each core to handle the same volume of I/O with reduced CPU usage.

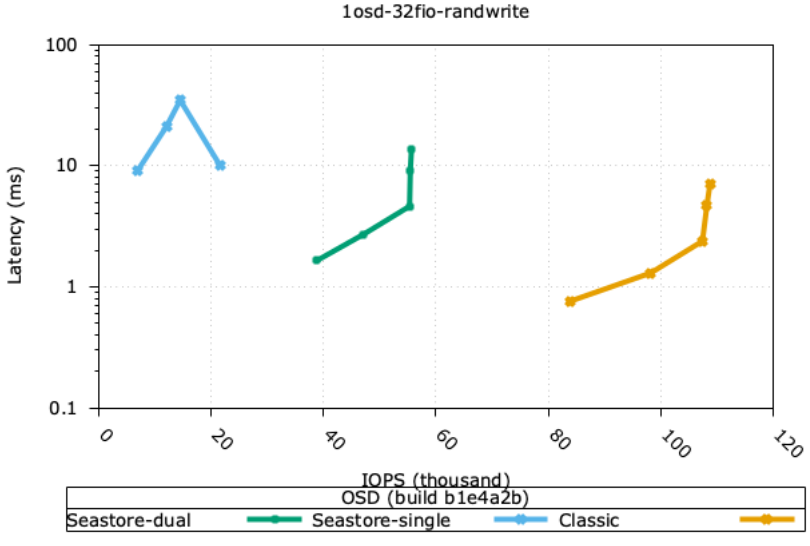
- CPU core pinning to reactor strategy

Crimson progress after 56 weeks

- **Robustness**: Over 100 pull requests have been merged
- **Coroutines**: (support in C++20) any new code added to Crimson is highly prioritised to be implemented with coroutines.
- **Seastar Reactor Options**: exposed some of these options as Ceph configurables
- **SeaStore optimisations**: conduct extensive testing, gain a deeper understanding of system behaviors, and prioritize addressing the most impactful problems
    - Partial Reads PR
    - Cache MD during cleanup
- **Periodic status reports**: for development and optimization purposes and are continuously evolving.

Crimson Performance





- Crimson performs better than Classic OSD for random read 4k
- Opportunity to improve for random write 4k

CPU core reactor pinning

CPU core reactor pinning

- Delivered PR 60822 to select the CPU reactor pining strategy:
    - OSD Balanced
    - NUMA separated
- Caveat: only for Intel HT architectures, not tested on AMD SMT
- Detailed Ceph Performance Blog https://ceph.io/en/news/blog/2025/crimson-balance-cpu-part1/
- Simplified and improved by Sam Just in PR 63137

CPU core reactor pinning

```
hboard --cyanstore --redirect-output --crimson --crimson-smp 3 --no-restart --crimson-balance-cpu osd
```

The following is the corresponding CPU distribution:

```
loading 3 .out files ...
== osd_0_cyan_3osd_3react_newbal_threads.out ==
== osd_1_cyan_3osd_3react_newbal_threads.out ==
== osd_2_cyan_3osd_3react_newbal_threads.out ==
     ---------------- Socket 0 ---------------- +      ---------------- Socket 1 ----------------
       0     1     2     3     4     5     6      +        0     1     2     3     4     5     6
     +-----+-----+-----+-----+-----+-----+------+ +      +-----+-----+-----+-----+-----+-----+------+
   0 |  R.0 + R.0 + R.0 + R.2 + R.2 + R.2 +  .   | +   28 |  R.1 + R.1 + R.1 +  .  +  .  +  .  +  .   |
   7 |   .  +  .  +  .  +  .  +  .  +  .  +  .   | +   35 |   .  +  .  +  .  +  .  +  .  +  .  +  .   |
  14 |   .  +  .  +  .  +  .  +  .  +  .  +  .   | +   42 |   .  +  .  +  .  +  .  +  .  +  .  +  .   |
  21 |   .  +  .  +  .  +  .  +  .  +  .  +  .   | +   49 |   .  +  .  +  .  +  .  +  .  +  .  +  .   |
     +-----+-----+-----+-----+-----+-----+------+ +      +-----+-----+-----+-----+-----+-----+------+
  56 |   .  +  .  +  .  +  .  +  .  +  .  +  .   | +   84 |   .  +  .  +  .  +  .  +  .  +  .  +  .   |
  63 |   .  +  .  +  .  +  .  +  .  +  .  +  .   | +   91 |   .  +  .  +  .  +  .  +  .  +  .  +  .   |
  70 |   .  +  .  +  .  +  .  +  .  +  .  +  .   | +   98 |   .  +  .  +  .  +  .  +  .  +  .  +  .   |
  77 |   .  +  .  +  .  +  .  +  .  +  .  +  .   | +  105 |   .  +  .  +  .  +  .  +  .  +  .  +  .   |
     +-----+-----+-----+-----+-----+-----+------+ +      +-----+-----+-----+-----+-----+-----+------+
(3 12) jjperez@loses-Air:/tmp
```

IOP Cost estimation

IOP cost estimation for Crimson

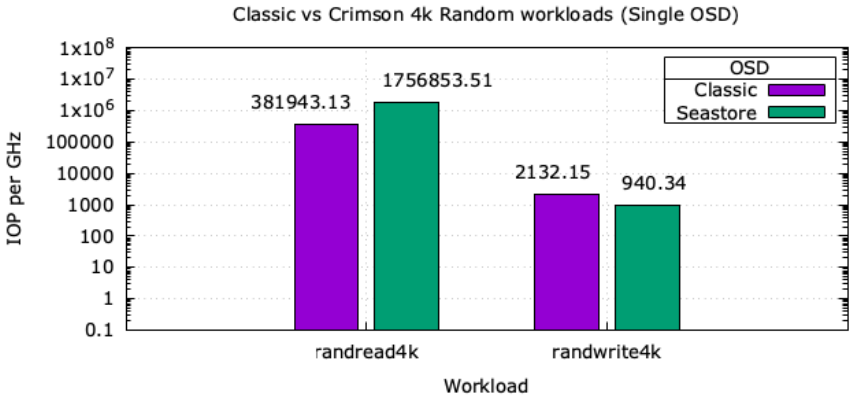
Query from Kyle Bader

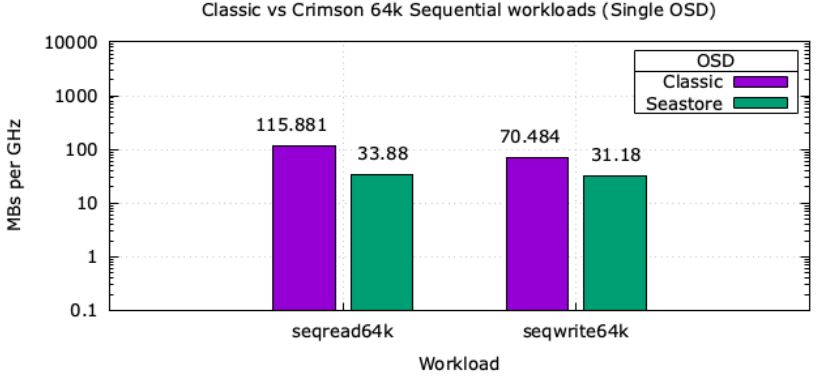
- Crimson performance metrics revisited (equation showing the estimations)

$$\texttt{IOP per GHz} = \frac{IOPkHz}{(n \times 2.2GHz \times x_i)}$$

- Code (mostly Python) to collect, filter, transform and present (as Pandas data frames) the OSD reactor performance measurements
- Public project repo https://github.com/perezjosibm/ceph-aprg/tree/main
- Production of custom performance reports, discussions on the weekly Crimson call (charts and sections of the report)

IOP cost estimation for Crimson



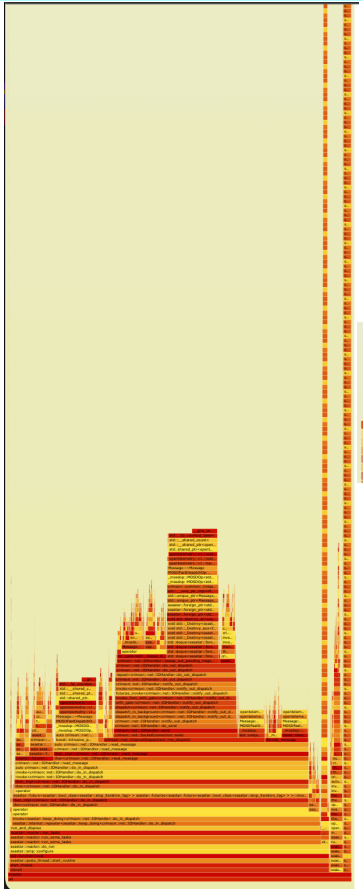


These estimations are based on a dual-socket Intel(R) Xeon(R) Platinum 8276M CPU @ 2.20GHz (56 cores each socket)

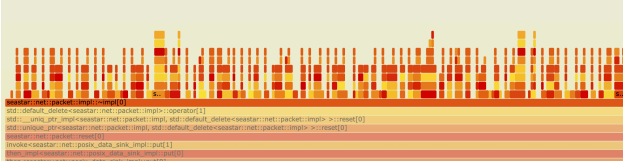
Crimson vs. Asynchronous messenger

Crimson vs Classic (Asynchronous) Messenger

- Performance testing of the Messenger component of the OSD
- Implemented a custom test driver trigger script to execute the messenger benchmark (written by Yinxing Cheng as a standalone) to traverse over:
  - Number of clients, number of CPU cores
  - NUMA Separated vs Balanced CPU pinning
  - Monitor and collect measurements from Seastar
- Analysis based on flame graphs
  - Implemented a filter to deal with huge towers in the flame graphs
- Identifying bottlenecks and recommendations for optimisations on going

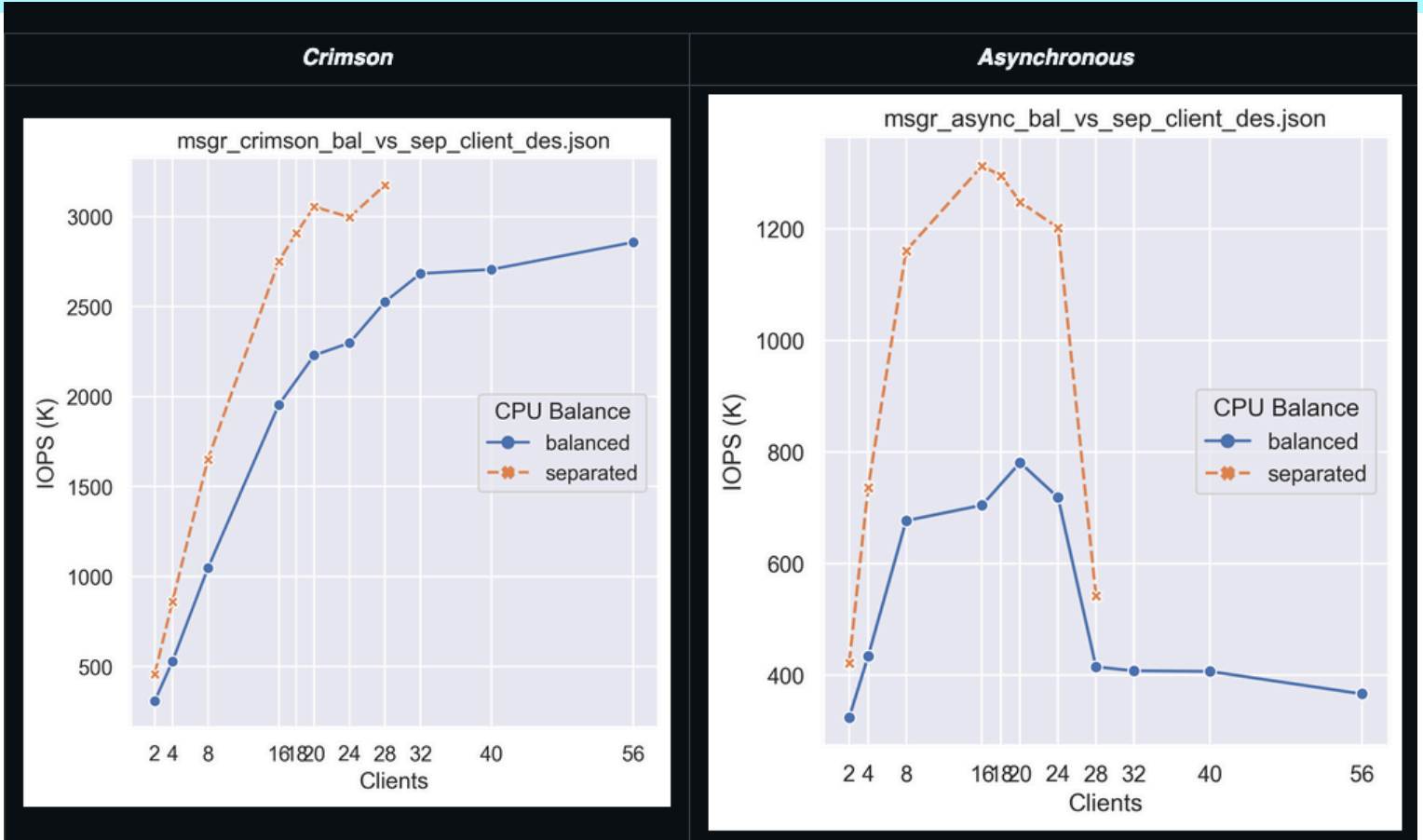


Tall towers occur in code path/stacks that involve lambda resolution of the asynchronous computation in Seastar (future/ promises)



Essentially, each code stack is encoded as a *multiset* (item with number of occurrences)

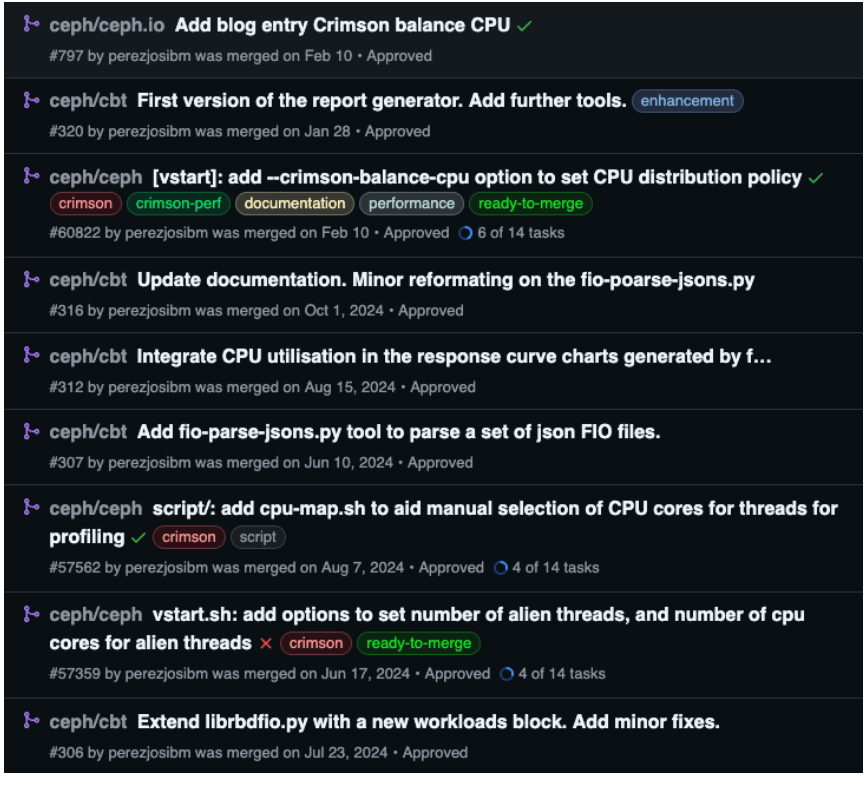
Crimson vs Classic (Asynchronous) Messenger



Code Contributions to the Ceph Benchmark Toolkit

CBT PRs

- Defined a ‘workload’ section in the test plan .yaml schema for modular test execution (PR 306)
- Implemented an automated unit test generator to support regression testing when refactoring the exiting code (PR 320)
    - Based on the notion of object serialisation
- Extending the documentation (PR 316)
- Extending the tools in the Crimson folder
    - Collect, transform, filter data from measurements (monitoring) and present as Pandas data frames



Future Ideas

Future Ideas

- Performance analysis of coroutines in Seastar
- Port to Crimson the https://github.com/taodd/cephtrace project on dynamic latency monitoring (Dongdong Tao, Cephalocon 2023)
- Memory efficient atomic shared pointers: reduce contention, e.g. avoid shared mutable state via the "blue/green deployment" pattern (Arthur O'Dwyer - CppCon 2020)

Feedback from the Community