# What is the fastest Garbage Collector in Java 8?

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OpenJDK 8 has several Garbage Collector algorithms, such as *Parallel GC*, *CMS* and *G1*. Which one is the fastest? What will happen if the default GC changes from Parallel GC in Java 8 to G1 in Java 9 (as currently proposed)? Let's benchmark it.

## Benchmark methodology

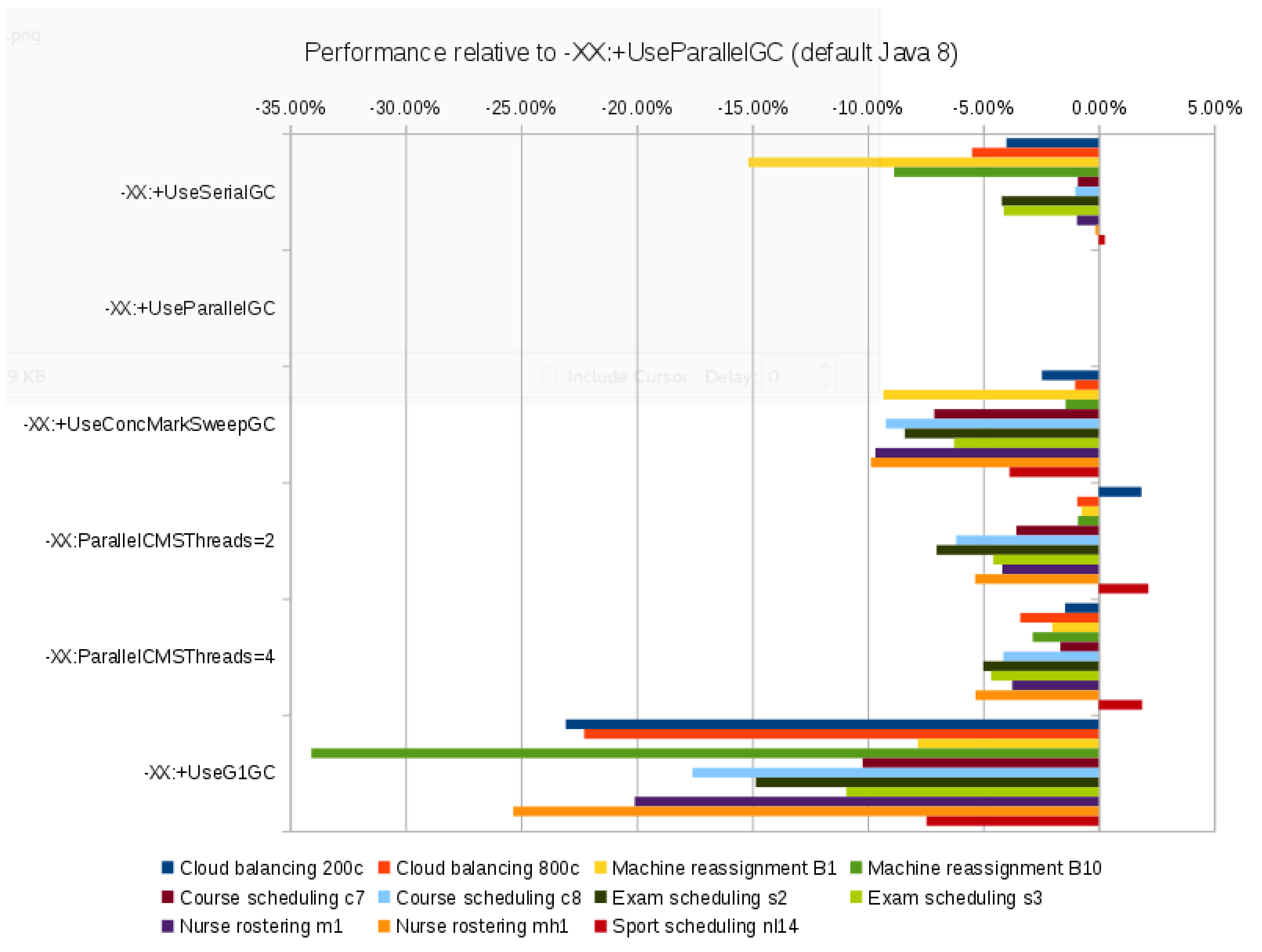
- Run the same code 6 times with a different VM argument (`-XX:+UseSerialGC`, `-XX:+UseParallelGC`, `-XX:+UseConcMarkSweepGC`, `-XX:ParallelCMSThreads=2`, `-XX:ParallelCMSThreads=4`, `-XX:+UseG1GC`).
- Each run takes about 55 minutes.
- Other VM arguments: `-Xmx2048M -server`
  OpenJDK version: `1.8.0_51` (currently the latest version)
  Software: `Linux version 4.0.4-301.fc22.x86_64`
  Hardware: `Intel® Core™ i7-4790 CPU @ 3.60GHz`
- Each run solves 13 planning problems with OptaPlanner. Each planning problem runs for 5 minutes. It starts with a 30 second JVM warm up which is discarded.
- Solving a planning problem involves **no IO** (except a few milliseconds during startup to load the input). **A single CPU is completely saturated.** It constantly creates many short-lived objects, and the GC collects them afterwards.
- The benchmarks measure the number of scores that can be calculated per millisecond. Higher is better. Calculating a score for a proposed planning solution is non-trivial: it involves many calculations, including checking for conflicts between every entity and every other entity.

To reproduce these benchmarks locally, build optaplanner from source and run the main class GeneralOptaPlannerBenchmarkApp.

## Benchmark results

### Executive summary

For your convenience, I've compared each Garbage Collector type to the default in Java 8 (Parallel GC).



The results are clear: **That default (Parallel GC) is the fastest.**

## Raw benchmark numbers

| Garbage Collector | Cloud balancing 200c | Cloud balancing 800c | Machine reassignment B1 | Machine reassignment B10 | Course scheduling c7 | Course scheduling c8 | Exam scheduling s2 | Exam scheduling s3 | Nurse rostering m1 | Nurse rostering mh1 | Sport scheduling nl14 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| `-XX:+UseSerialGC` | 121211 | 102072 | 239278 | 54637 | 10821 | 14370 | 17095 | 10130 | 7389 | 6667 | 2234 |
| `-XX:+UseParallelGC` (default Java 8) | 126248 | 107991 | 282055 | 59944 | 10919 | 14517 | 17843 | 10564 | 7459 | 6676 | 2228 |
| `-XX:+UseConcMarkSweepGC` | 123150 | 106889 | 255775 | 59087 | 10142 | 13180 | 16346 | 9903 | 6738 | 6018 | 2142 |
| `-XX:ParallelCMSThreads=2` | 128591 | 106992 | 279968 | 59406 | 10530 | 13621 | 16591 | 10082 | 7148 | 6319 | 2276 |
| `-XX:ParallelCMSThreads=4` | 124415 | 104328 | 276401 | 58234 | 10738 | 13918 | 16952 | 10072 | 7180 | 6320 | 2270 |
| `-XX:+UseG1GC` (default Java 9?) | 97146 | 83952 | 259981 | 39522 | 9803 | 11965 | 15195 | 9410 | 5961 | 4985 | 2062 |
| Dataset scale | 120k | 1920k | 500k | 250000k | 217k | 145k | 1705k | 1613k | 18k | 12k | 4k |

## Relative benchmark numbers

| Garbage Collector | Average | Cloud balancing 200c | Cloud balancing 800c | Machine reassignment B1 | Machine reassignment B10 | Course scheduling c7 | Course scheduling c8 | Exam scheduling s2 | Exam scheduling s3 | Nurse rostering m1 | Nurse rostering mh1 | Sport scheduling nl14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| `-XX:+UseSerialGC` | -4.05% | -3.99% | -5.48% | -15.17% | -8.85% | -0.90% | -1.01% | -4.19% | -4.11% | -0.94% | -0.13% | +0.27% |
| `-XX:+UseParallelGC` (default Java 8) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| `-XX:+UseConcMarkSweepGC` | -6.23% | -2.45% | -1.02% | -9.32% | -1.43% | -7.12% | -9.21% | -8.39% | -6.26% | -9.67% | -9.86% | -3.86% |
| `-XX:ParallelCMSThreads=2` | -2.67% | +1.86% | -0.93% | -0.74% | -0.90% | -3.56% | -6.17% | -7.02% | -4.56% | -4.17% | -5.35% | +2.15% |
| `-XX:ParallelCMSThreads=4` | -2.94% | -1.45% | -3.39% | -2.00% | -2.85% | -1.66% | -4.13% | -4.99% | -4.66% | -3.74% | -5.33% | +1.89% |
| **`-XX:+UseG1GC` (default Java 9?)** | **-17.60%** | -23.05% | -22.26% | -7.83% | -34.07% | -10.22% | -17.58% | -14.84% | -10.92% | -20.08% | -25.33% | -7.45% |
| Dataset scale | | 120k | 1920k | 500k | 250000k | 217k | 145k | 1705k | 1613k | 18k | 12k | 4k |

## Should Java 9 default to G1?

There is a proposal to **make G1 the default Garbage Collector in OpenJDK9 for servers**. My first reaction is to **reject this proposal**:

- G1 is `17.60%` is slower on average.
- G1 is consistently slower on every use case for every dataset.
- On the biggest dataset (Machine Reassignment B10), which dwarfs any of the other datasets in size, G1 is `34.07%` is slower.
- If the default GC differs between developer machines and servers, then developer benchmarks become less trustworthy.

On the other hand, there are a few nuances to note:

- G1 focuses on limiting GC pauses, instead of throughput. For these use cases (with heavy calculations) GC pause length mostly doesn't matter.
- This was an (almost) single-threaded benchmark. Further benchmarking with multiple solvers in parallel or multithreaded solving might influence results.
- G1 is recommended for a heap size of at least `6 GB`. This benchmark used a heap size of only `2 GB` and even that size is only needed for the biggest dataset (Machine Reassignment B10).

Heavy calculations is just one of the many things that OpenJDK is used for: it's just 1 stakeholder in this community wide debate. If other stakeholders (such as web services) prove otherwise, maybe it's worth changing the default GC. But **show me the benchmarks** on real projects first!

## Conclusion

In Java 8, the default Garbage Collector (Parallel GC) is generally the best choice for OptaPlanner use cases.

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