Improvements to GHC’s parallel garbage collector

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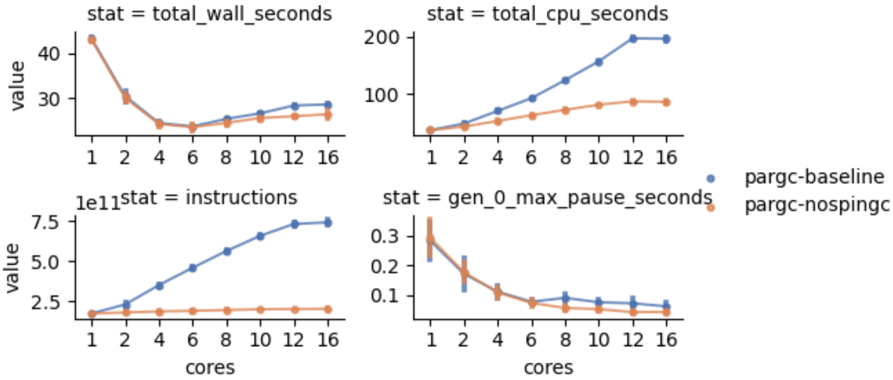
The Haskell Consultants

Introduction

- Independent work conducted in summer of 2020/2021.
- Will be released in GHC 9.2
- Linux, amd64
- Improved cross-thread synchronisation in the garbage collector drastically reduces cpu time
  - Measurement of improvement
  - Description of changes
  - Some experiments

Measurement of improvement

```
cd libraries/Cabal && ghc --make -j$i Setup.hs
```



Environment: AMD zen3, 8 physical cores, 16GB, Laptop, hyper-threading on, 12 core cpuset

sched_yield in 60 seconds

implemented in `kernel/sched/fair.c`

GHC issue 9221

From `sched_yield (2)` man page:

> *sched_yield() causes the calling thread to relinquish the CPU. The thread is moved to the end of the queue for its static priority and a new thread gets to run.*
>
> ...
>
> *sched_yield() is intended for use with real-time scheduling policies (i.e., SCHED_FIFO or SCHED_RR). Use of sched_yield() with nondeterministic scheduling policies such as SCHED_OTHER is unspecified and very likely means your application design is broken.*

`sched_yield` is either:

- A busy spin;
- Effectively lowering our priority by forfeiting our timeslice.

Because ghc launches assemblers and linkers, it more often experiences a lowering of priority.

Removing sched_yield calls

Don't use `sched_yield` for busy-waits, use mutexes and condition variables.

Take care to identify and maintain invariants, and to minimize `pthread_cond_broadcast`.

Three places:

- GC entry
- GC exit
- work stealing

GC entry and exit

1. All worker threads change from `INACTIVE` to `STANDING_BY` and block;
2. The gc leader waits in `waitForGcThreads` for all worker threads to reach `STANDING_BY`;
3. The gc leader does some initialisation;
4. The gc leader calls `wakeup_gc_threads`, which sets the worker threads to `RUNNING` and wakes them up;
5. All worker threads run out of work and change from `RUNNING` to `WAITING_TO_CONTINUE` and block;
6. The gc leader waits in `shutdown_gc_threads` for all worker threads to reach `WAITING_TO_CONTINUE`;
7. The gc leader does some cleanup;
8. The gc leader calls `releaseGcThreads`, which sets all worker threads to `INACTIVE` and wakes them up.

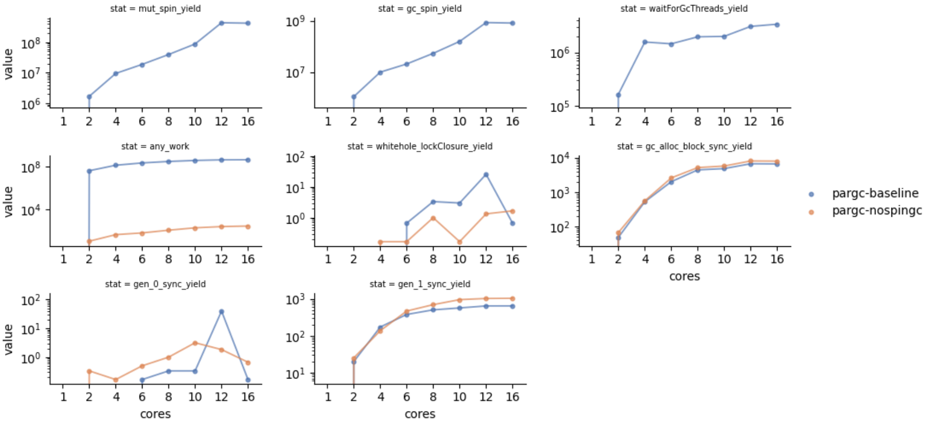
work stealing

1. Track the number of threads working with global variable `gc_running_threads`;
2. Threads that aren’t working are waiting for work to appear in other threads’ queues;
3. `gc_running_threads` reaching zero is the stop condition.

How to wake up threads when blocks are ready?

Signal (not broadcast) when a block is ready and `gc_running_threads < n`.

Measuring sched_yield



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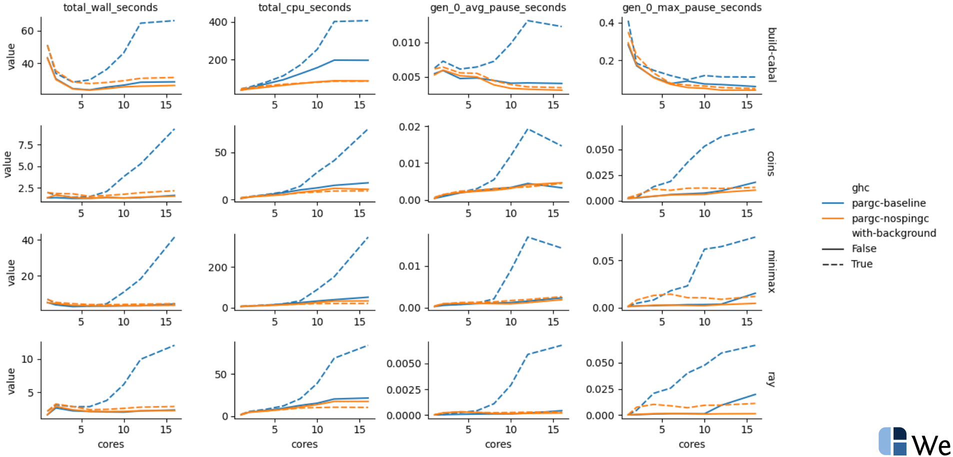
Introducing background noise

Run the same benchmarks, while running ‘stress-ng‘ simulataneously

```
stress-ng --cpu 0 --cpu-method ackerman --cpu-load 40
```



Future work

- Investigate removing remaining `sched_yield` calls;
- Benchmarking on Windows, Darwin, ARM, etc.
- Investigate `stack` and `cabal-install` exploit `ghc -j`

Links

code: https://github.com/duog/ghcbench

slides: https://github.com/duog/ghcbench/tree/master/hiw/hiw.pdf

ghc commits:

- baseline
  - link: https://gitlab.haskell.org/duog/ghc/-/tree/pargc-baseline
  - commit: 3a536b890f88c16166f4d68ecf1ed8f49dd6f661
- noanywork:
  - link: https://gitlab.haskell.org/duog/ghc/-/tree/pargc-noanywork
  - commit: ce0f280908c29c1608c4f62002d325e6b931d98d
- nospingc:
  - link: https://gitlab.haskell.org/duog/ghc/-/tree/pargc-nospingc
  - commit: 0dc550105acedb714f0902cfb3dfd8f03fa08272