Lecture 29 — Liar, Liar

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Liar, Liar

Sampling Based Profiling

Let’s open with a video that illustrates one of the problems with sampling-based profiling:

`https://www.youtube.com/watch?v=jQDjJRYmeWg`

Is this fake?

In the Criminal Justice System...

Who can we trust?

Profiler as Prosecutor?

The analogy works well even if the profiler is a program and not a state agency.

TV shows make it all very neat because the mystery needs to be solved within the time limit of the episode or season.

In reality, there is nuance when a “DNA match is found”.

Case Closed?

The presence of the suspect's DNA is *consistent* with the prosecution's theory of the crime, but does not conclusively prove anything on its own.

Only the totality of the evidence, considered together, would lead to a conclusion about whether that narrative is true.

Both Things Can Be Wrong

We'll consider some examples where the profiler gets it wrong on each part: either the data collection or the narrative that we get is incorrect.

What's wrong in the helicopter example: data collection or narrative?

Part II

Lies from Metrics

Lying perf counters

While app-specific metrics can lie too,
mostly we'll talk about CPU perf counters.

Reference: Paul Khuong,
`http://www.pvk.ca/Blog/2014/10/19/performance-optimisation-~-writing-an-essay/`

mfence

We've talked about `mfence`.
Used in spinlocks, for instance.

Profiles said: spinlocking didn't take much time.
Empirically: eliminating spinlocks = better than expected!

Exploring the lie

Next step: create microbenchmarks.

Memory accesses to uncached locations,
or computations,

surrounded by store pairs/mfence/locks.

Use perf to evaluate impact of mfence vs lock.

perf for lock

```
$ perf annotate -s cache_misses
[...]
     0.06 :         4006b0:       and    %rdx,%r10
     0.00 :         4006b3:       add    $0x1,%r9
     ;; random (out of last level cache) read
     0.00 :         4006b7:       mov    (%rsi,%r10,8),%rbp
    30.37 :         4006bb:       mov    %rcx,%r10
     ;; foo is cached, to simulate our internal lock
     0.12 :         4006be:       mov    %r9,0x200fbb(%rip)
     0.00 :         4006c5:       shl    $0x17,%r10
     [... Skipping arithmetic with < 1% weight in the profile]
     ;; locked increment of an in-cache "lock" byte
     1.00 :         4006e7:       lock incb 0x200d92(%rip)
    21.57 :         4006ee:       add    $0x1,%rax
     [...]
     ;; random out of cache read
     0.00 :         400704:       xor    (%rsi,%r10,8),%rbp
    21.99 :         400708:       xor    %r9,%r8
     [...]
     ;; locked in-cache decrement
     0.00 :         400729:       lock decb 0x200d50(%rip)
    18.61 :         400730:       add    $0x1,%rax
     [...]
     0.92 :         400755:       jne    4006b0 <cache_misses+0x30>
```

lock's effects

Reads take 30 + 22 = 52% of runtime
Locks take 19 + 21 = 40%.

perf for mfence

```
$ perf annotate -s cache_misses
[...]
     0.00 :         4006b0:       and    %rdx,%r10
     0.00 :         4006b3:       add    $0x1,%r9
     ;; random read
     0.00 :         4006b7:       mov    (%rsi,%r10,8),%rbp
    42.04 :         4006bb:       mov    %rcx,%r10
     ;; store to cached memory (lock word)
     0.00 :         4006be:       mov    %r9,0x200fbb(%rip)
     [...]
     0.20 :         4006e7:       mfence
     5.26 :         4006ea:       add    $0x1,%rax
     [...]
     ;; random read
     0.19 :         400700:       xor    (%rsi,%r10,8),%rbp
    43.13 :         400704:       xor    %r9,%r8
     [...]
     0.00 :         400725:       mfence
     4.96 :         400728:       add    $0x1,%rax
     0.92 :         40072c:       add    $0x1,%rax
     [...]
     0.36 :         40074d:       jne    4006b0 <cache_misses+0x30>
```

mfence's effects

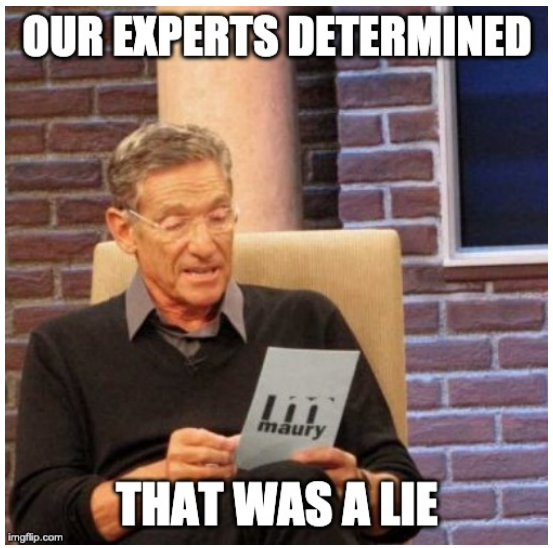
Looks like the reads take 85% of runtime,
while the mfence takes 15% of runtime.

Bigger picture

Must also look at total # of cycles.

No atomic/fence:	2.81e9 cycles
lock inc/dec:	3.66e9 cycles
mfence:	19.60e9 cycles

That 15% number is a total lie.



Conclusions

- mfence underestimated;
- lock overestimated.

Why?

mfence = pipeline flush,
costs attributed to instructions being flushed.

Skid

Another cause for the attributions of which instructions are expensive being wrong is something called skid.

Skid is the time between when the counter overflows (trigger the sample) and when the actual sample is taken.

Made-Up Skid Example

A made-up example of what that might look like:

```
ld r1,0x12341234     0.1%
add r2,r3            1.0%
sub r3,r4            1.0%
NOP                 27.0%
```

The NOP is obviously not the cause here; it's the load instruction that really is the expensive one.

Part III

The Long Tail

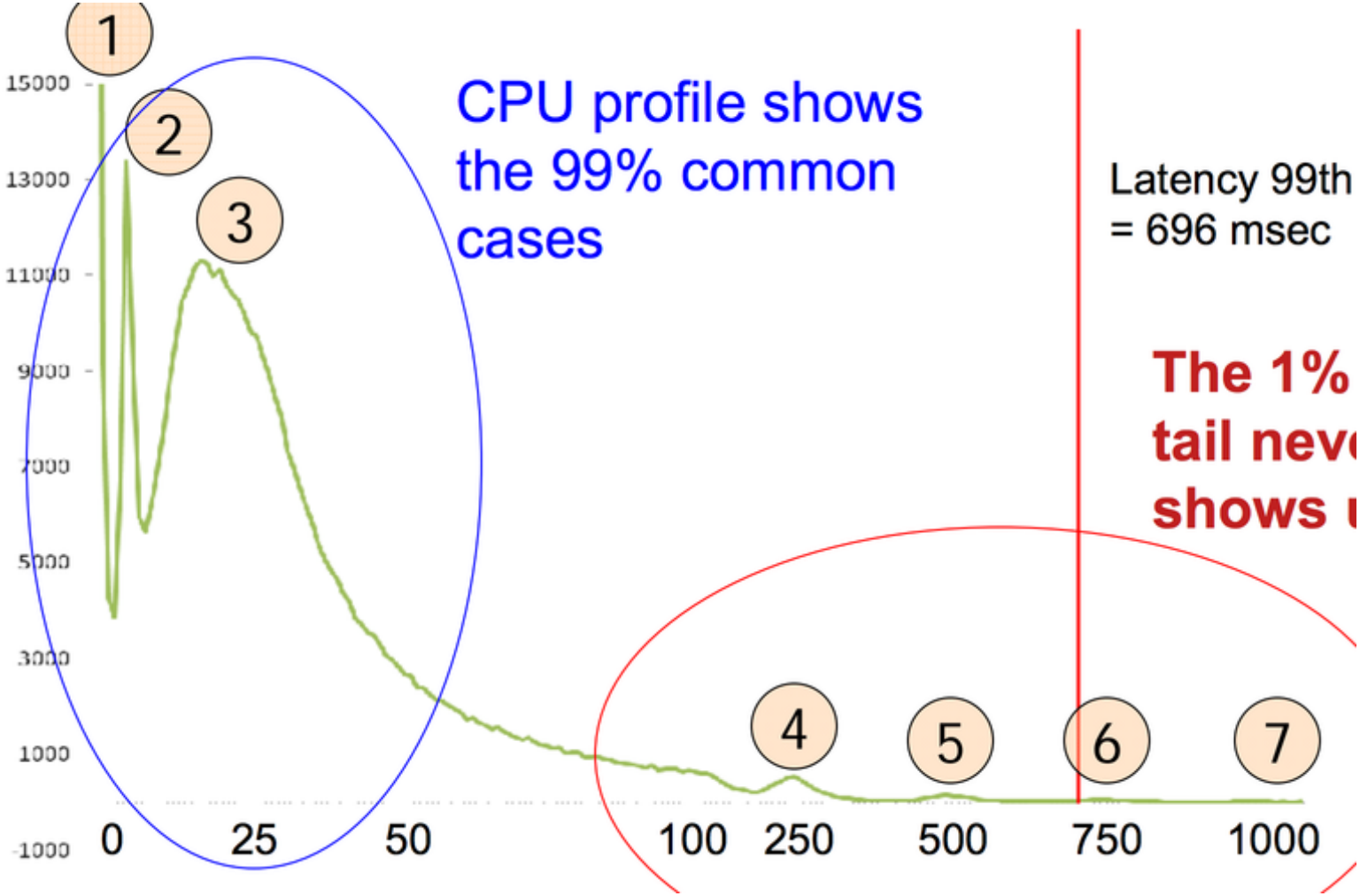
The Long Tail

Suppose we have a task that's going to get distributed over multiple computers (like a search).

If we look at the latency distribution, the problem is mostly that we see a long tail of events.

When we are doing a computation or search where we need all the results, we can only go as the slowest step.

Grab the Tiger by the Tail



Explaining the Peaks

1. Found in RAM
2. Disk Cache
3. Disk
4. and above... very strange!

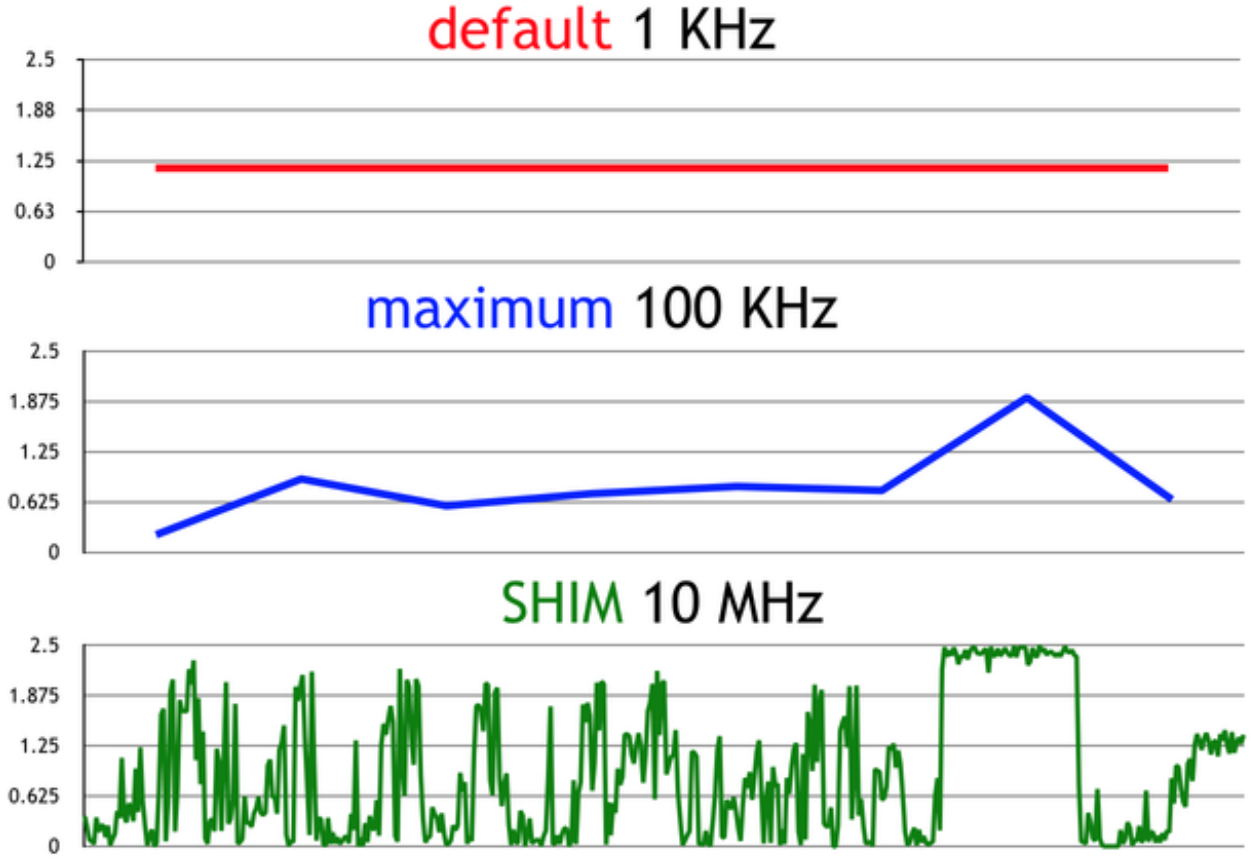
Why 250, 500, 750, 1000?

Answer: CPU throttling!

This was happening on 25% of disk servers at Google, for an average of half an hour a day!

Faster than a Speeding Bullet

Another problem with sampling, this time from Lucene:



Why is perf limited to 100 KHz?

Processing Interrupts

Answer: perf samples are done with interrupts (slow).

If you crank up the rate of interrupts, before long, you are spending all your time handling the interrupts rather than doing useful work.

SHIM gets around this by being more invasive.

This produces a bunch of data which can be dealt with later.

Part IV

Lies from Counters

Counter This

Rust compiler hackers were trying to include support for hardware performance counters (what perf reports).

To make counters as deterministic as possible:

- disable Address Space Layout Randomization (security mitigation; but, randomized pointer addresses affect hash layouts);
- subtract time spent processing interrupts (IRQs);
- profile one thread only (if you can, in your context).

Problem?

Edith Binch @eddyb_r · Nov 4

AMD: we made a really clever speculative thing that keeps executing instructions normally even
me: okay but what do you do when it fails
AMD: 😅it uhhh rolls back time to the point of divergence😅
me: cool, cool, but did you remember you also roll back the perf counters?
AMD: 😬

2 2 30

Part V

Lies about Calling Context

Profilers, Lying?

This part is somewhat outdated now, as it's a pretty specific technical problem that especially arises under the `gprof` tool.

It's still a good example of lying tools, though.

Reference: Yossi Kreinin,
`http://www.yosefk.com/blog/how-profilers-lie-the-cases-of-gprof-and-kcachegrind.html`

gprof said what?

gprof uses two C standard-library functions: **profil()** and **mcount()**.

- **profil()**: asks glibc to record which instruction is currently executing (100$\times$/second).
- **mcount()**: records call graph edges; called by `-pg` instrumentation.

Getting it Wrong

Hence, **profil** information is statistical, while **mcount** information is exact.

gprof can draw unreliable inferences.

If you have a method `easy` and a method `hard`, each of which is called once, and `hard` takes up almost all the CPU time...

gprof might divide total time by 2 and report bogus results.

What's Wrong?

The following results from gprof are suspect (among others):

- contribution of children to parents;
- total runtime spent in self+children;

When are call graph edges right? Two cases:

- functions with only one caller (e.g. `f()` only called by `g()`); or,
- functions which always take the same time to complete (e.g. `rand()`).

Lies summary

Some results are exact;
some results are sampled;
some results are interpolated.

If you understand the tool,
you understand where it can go wrong.

Understand your tools!