Google

GWP-TSan

Zero-Cost Detection of Data Races in Production

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What is GWP-TSan?

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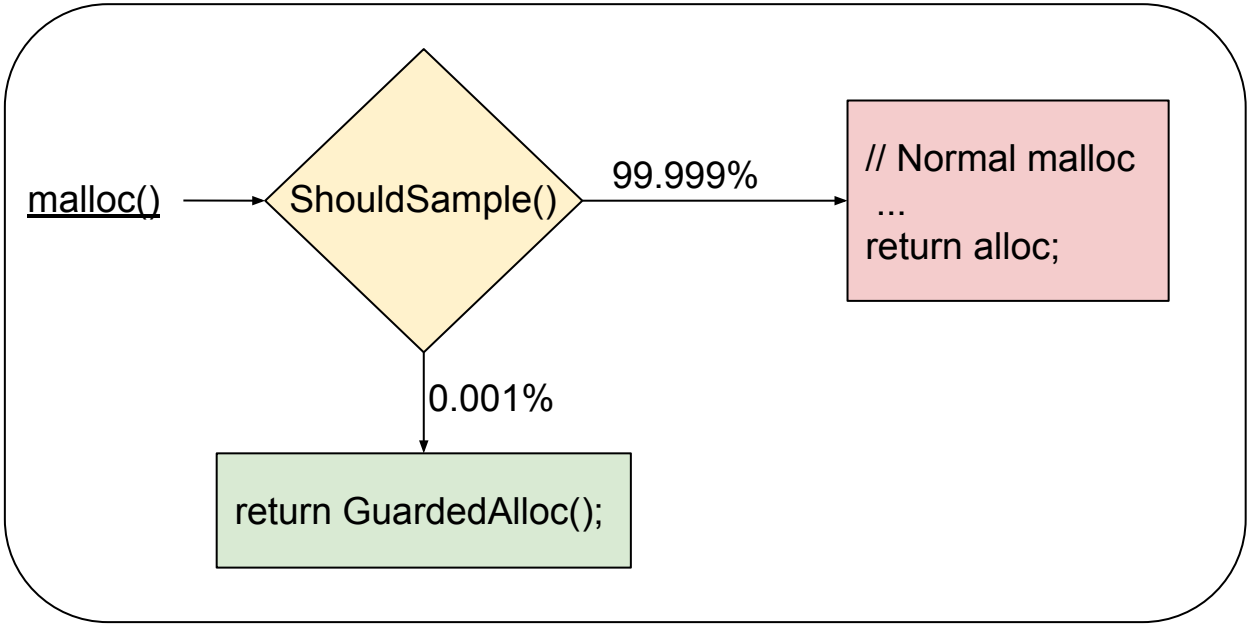
- “**G**WP-TSan **W**ill **P**rovide **T**hread **San**itization”

- Probabilistic data race detector (heap only).
  - Still under development.

- Built on top of GWP-ASan.

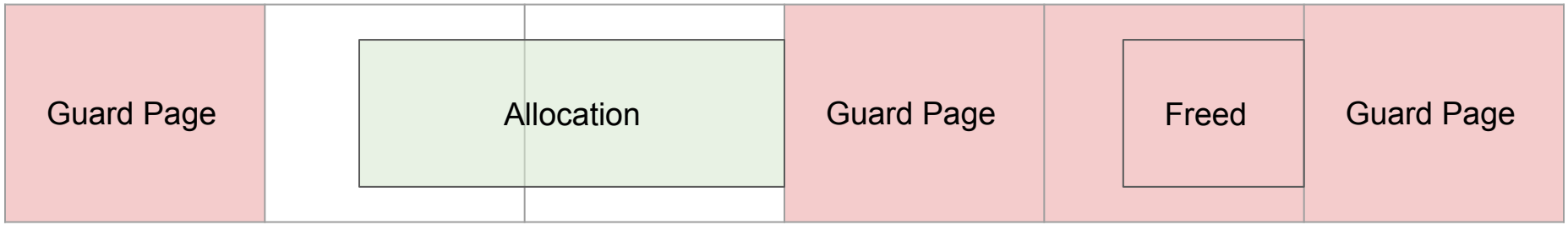
Background: GWP-ASan

- Tiny fraction of allocations (e.g. 1/100,000) routed to GWP-ASan.
  - Sampling rate adjusted for negligible CPU overhead.



Background: GWP-ASan

- Detects heap-buffer-overflows using **guard pages.**
- Detects use-after-frees by *mprotect*-ing freed memory**.**



Background: DataCollider

```
int racy_counter = 0;

int get_racy_counter() {
  return racy_counter;
}

void inc_racy_counter() {
  ++racy_counter;
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T1 →

1. Set breakpoint on a random memory access.
2. When breakpoint fires, remove breakpoint and set a watchpoint on the accessed memory.

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T1 →

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3. Wait.

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T1 → `return racy_counter;`

T2 → `++racy_counter;`

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2. When breakpoint fires, remove breakpoint and set a watchpoint on the accessed memory.
3. Wait.
4. If watchpoint fires while waiting, report a data race.

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DATA RACE!

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2. When breakpoint fires, remove breakpoint and set a watchpoint on the accessed memory.
3. Wait.
4. If watchpoint fires while waiting, report a data race.
5. Otherwise, remove watchpoint and continue execution.

GWP-TSan = GWP-ASan + DataCollider

- Periodically set watchpoints on GWP-ASan allocations.

- Report a data race when concurrent accesses to the same address are detected, with:
  - At least one write.
  - At least one non-atomic access.

Watchpoints

- DataCollider uses debug registers.
  - + Trap on accesses to specific address only.
  - - Only 4 debug registers.

- GWP-TSan uses *mprotect(PROT_NONE)* and SEGV handler.
  - - Trap on any access within the same 4KB page.
  - + Unlimited watchpoints.
  - + Potential use of Intel pkeys for speed.

Challenges

Atomic Accesses

Problem:

- Concurrent atomic accesses should not be reported as races.
- How to tell if an access is atomic?

Solution:

- LLVM backend pass to create a PC table of atomic access instructions.
- Read the table into memory during GWP-TSan initialization.
- O(1) *isAtomic()* check for any PC.

System Calls

Problem:

- Passing PROT_NONE memory to syscalls makes them fail with EFAULT.

Solution:

- Intercept glibc syscall wrappers.
- Remove watchpoints before syscalls.

Thank you!
(Feedback is welcome)