Targeted Memory Runtime Analysis

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Agenda

1. Introduction
2. General approach
3. Our approach using Ptrace
4. Our approach using Libpatch
5. Results
6. Future Work

Introduction

- Memory issues in C/C++ are still prevalent
  - Use-after-free
  - Memory leaks
  - Out-of-bound writes
  - And much more…

The general approach

- We want to verify accesses to dynamically allocated objects

- This means, for the library:
  1. Get control before the access
  2. Verify a valid access
  3. Unprotect the object
  4. Perform the access
  5. Re-protect the object

The general approach : Getting control before access

- By protecting dynamically allocated objects, accesses trigger a SIGSEGV
- We can then handle that signal with a custom signal handler
- Override *malloc/realloc/free* functions to add/remove protection

The general approach : Getting control before access

To protect dynamically allocated objects, we have implemented two methods:

- Pointer tainting using bits 47 to 63
    - System call arguments may be tainted!
        - Requires a kernel patch
- Use mmap() with PROT_NONE flag
    - Currently we allocate an entire page per object

The general approach : Bounds checking

In order to verify the access, use bounds checking

- We need information regarding the memory access:
  - Which register contains the tainted address
  - Information on base, index, scale, offset to compute address for bounds checking

- Use **Capstone** to disassemble instruction and retrieve relevant information

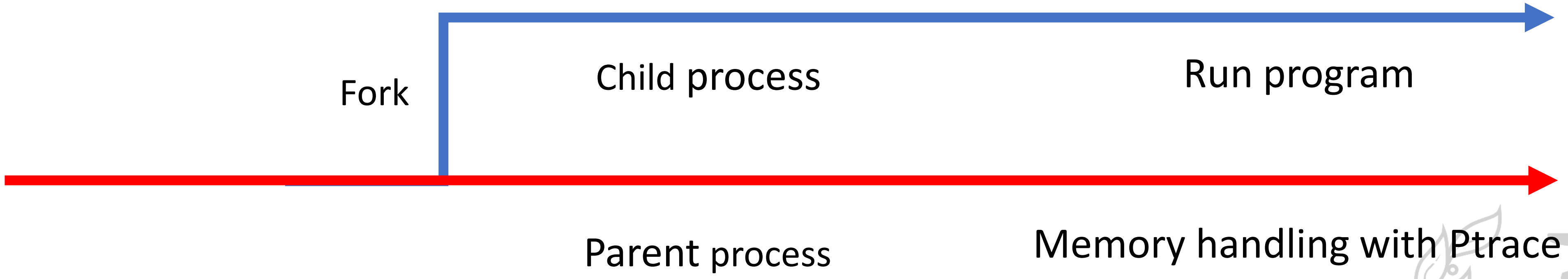
The general approach : Challenges

We still have some remaining challenges:

- How can we re-protect the object after the instruction?
- When using a custom signal handler, what restrictions apply for disassembling code (capstone)?

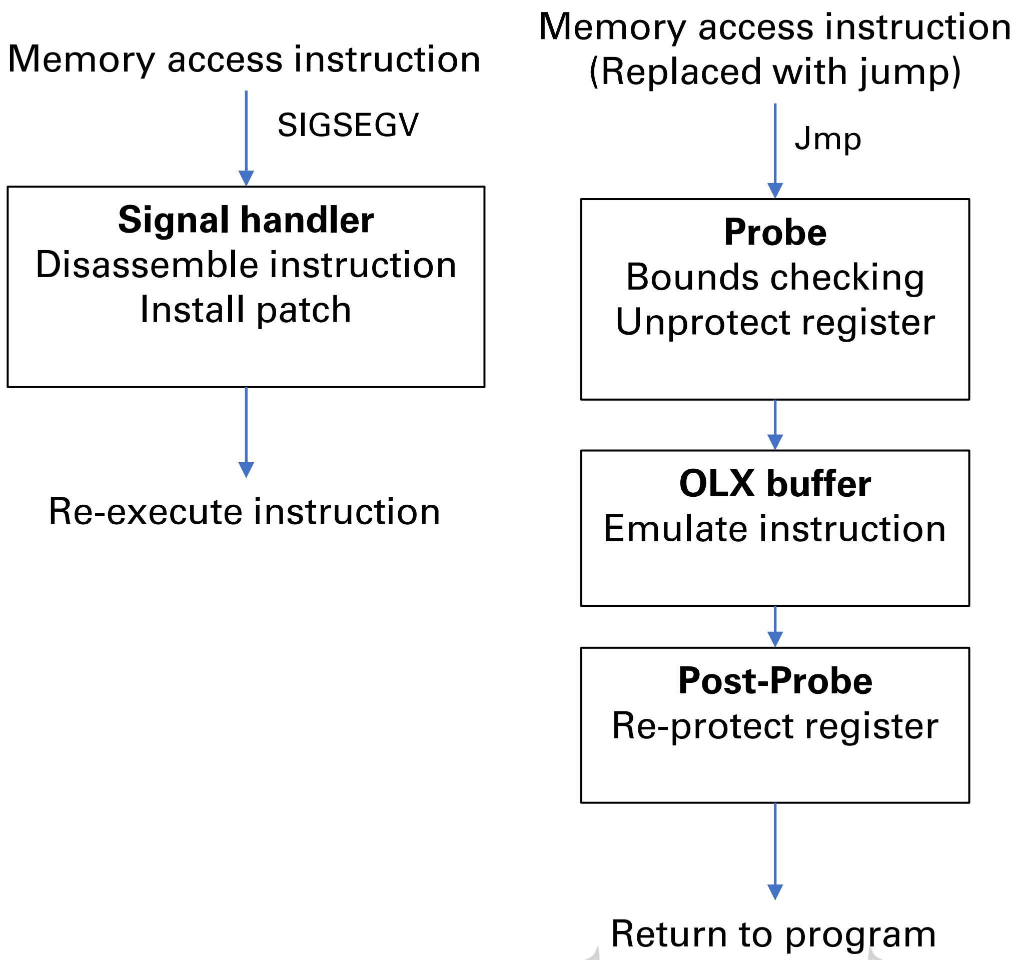
Our Ptrace approach

- Use Ptrace with 2 different processes
  - The child process runs the program with the special allocators
  - The parent process takes care of memory handling
  - Ptrace used for communication between processes and single-step
  - Using the CLONE_VM flag with clone() to make communication between the two threads easier



Our Libpatch approach

- The **Libpatch** library from Olivier Dion specializes in inserting probes at runtime
- Install patch at first encounter of instruction
- OLX buffer emulates instruction
- Post-probe allows us to re-protect address



Our Libpatch approach

- With the patch installed, no need to disassemble the same instruction multiple times
- For programs with repeated instructions with memory accesses, significant performance gain
- Prototype ready, ongoing development
- However, we need to install the patch in the signal handler

Result

We use the SPEC CPU 2017 benchmarks and micro-benchmarks:

- For the 505_mcf benchmark, 11 million tainted memory accesses for only 11k unique heap memory access instructions

- Majority of tainted objects used in those memory accesses are very small in size (< 127)

Future Work

- Finish implementation of our approach using Libpatch
  - Get a clear idea of its overhead

- **Targeted** memory analysis
  - Taint some memory allocations based on parameters (size, origin, …)