Xen Project
DEVELOPER AND DESIGN SUMMIT

SUPERFLUIDITY

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BUDAPEST, HUNGARY

uniprof: Transparent Unikernel Performance Profiling & Debugging

Florian Schmidt, Research Scientist, *NEC Europe Ltd.*

Unikernels?

- Faster, smaller, better!

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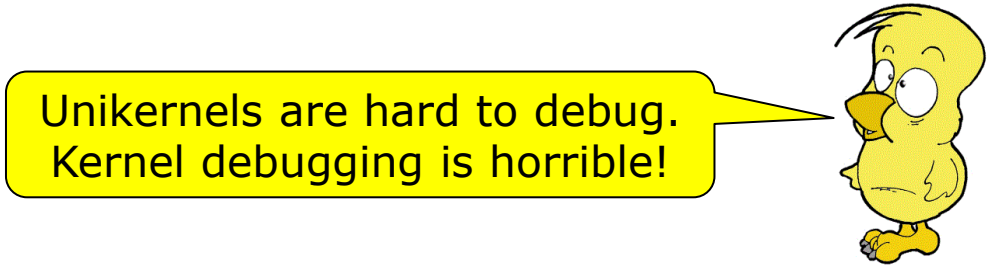

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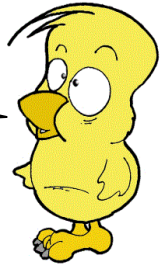
Unikernels are hard to debug.
Kernel debugging is horrible!



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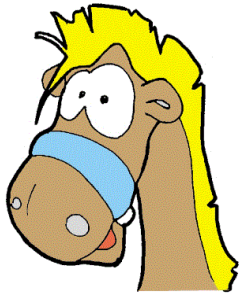
- Then you might say

But that’s not really true!
Unikernels are a single linked binary.
They have a shared address space.
You can just use gdb!



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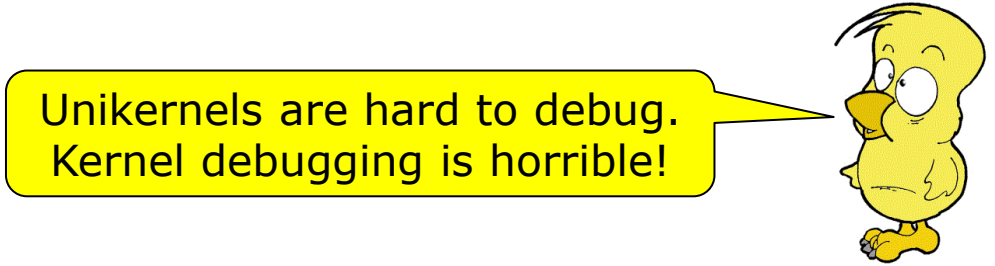

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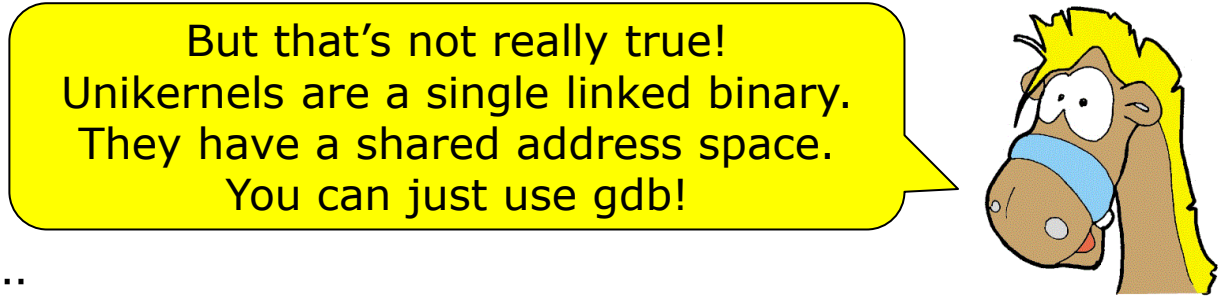

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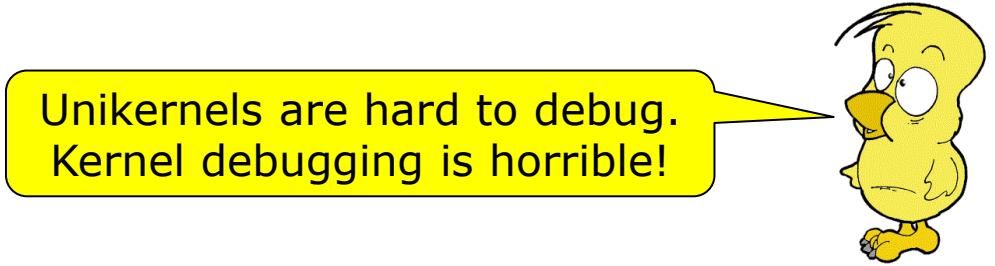

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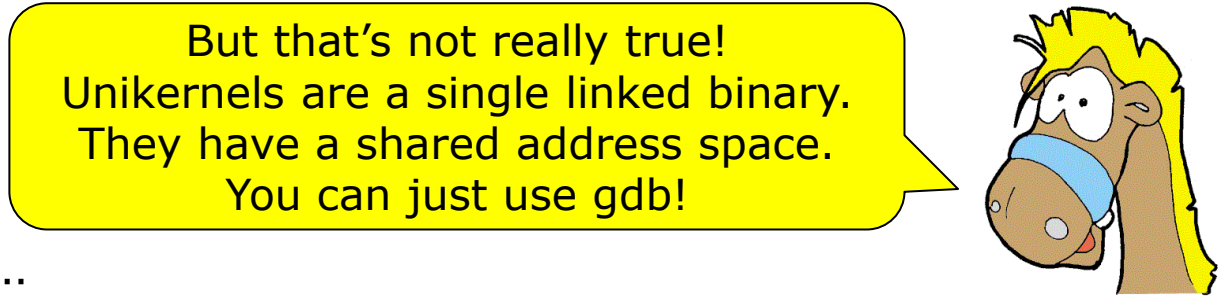

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- … we are admittedly lacking tools
- Such as effective profilers

Enter uniprof

Goals:

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So, a stack profiler

- Collect stack traces at regular intervals

```
call_main+0x278
main+0x1c
schedule+0x3a
monotonic_clock+0x1a
```

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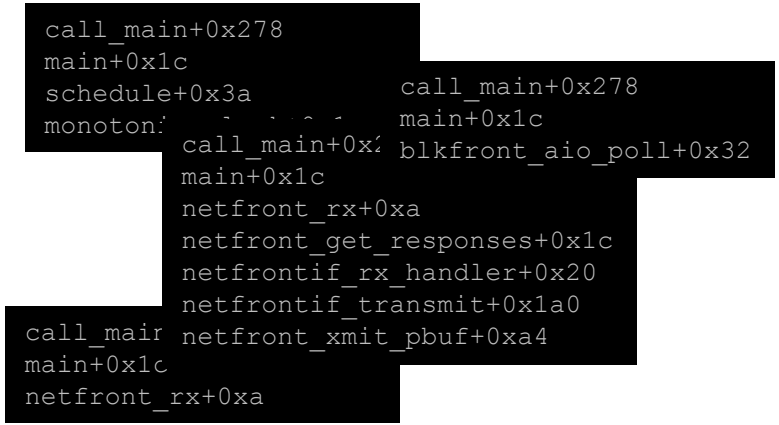

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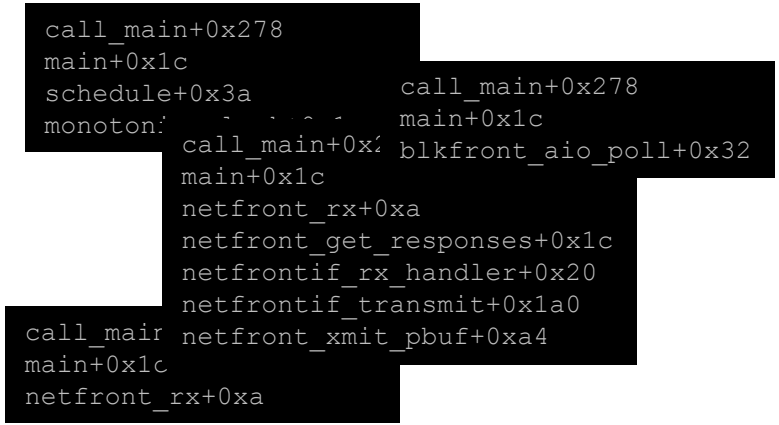
So, a stack profiler

- Collect stack traces at regular intervals
- Many of them
- Analyze which code paths show up often
  - Either because they take a long time
  - Or because they are hit often
- Point towards potential bottlenecks



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- Introspection tool
- Option to print call stack

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$ xenctx -f -s <symbol table file> <DOMID>
[...]
Call Trace:
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00000000000ffea0:   [<00000000000044f2>] two+0x52
00000000000ffef0:   [<00000000000046a6>] one+0x12
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- So if we run this over and over, we have a stack profiler
  - Well, kinda

xenctx

Downside: xenctx is slow

- Very slow: 3ms+ per trace
- Doesn’t sound like much, but really adds up (e.g., 100 samples/s = 300ms/s)
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- We interrupt the guest all the time
- Can’t walk stack while guest is running: race conditions
- High overhead can influence results!
- Low overhead is imperative for use on production unikernels

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First question: extend xenctx or write something from scratch?

- Spoiler: look at the talk title
- More insight when I come to the evaluation

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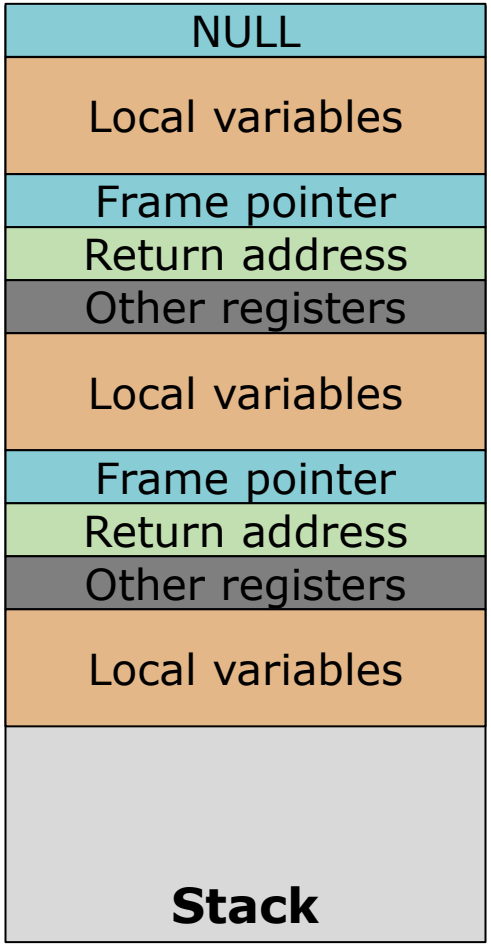
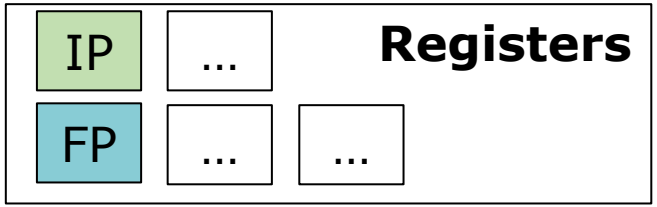
Symbol table (to resolve function names)

- Thankfully, this is easy again: extract symbols from ELF with `nm`



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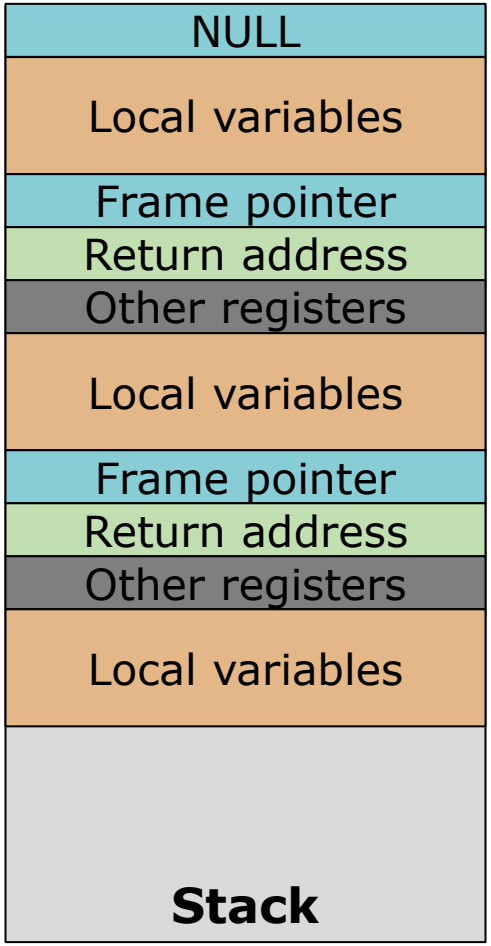

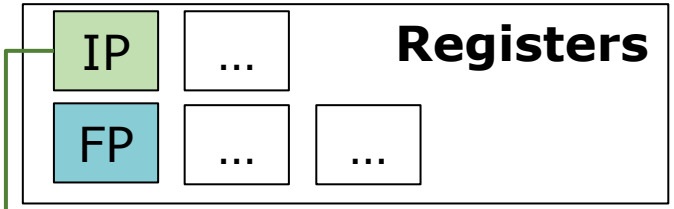


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function three() {
    […]
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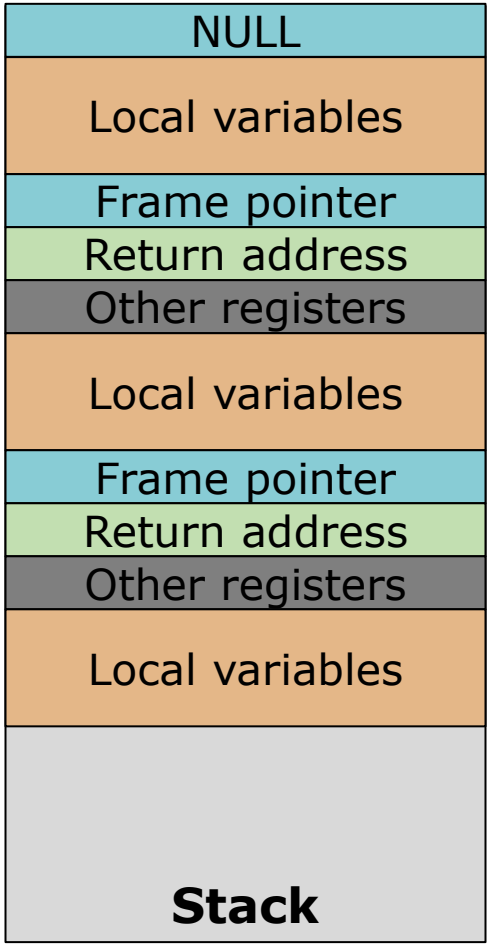

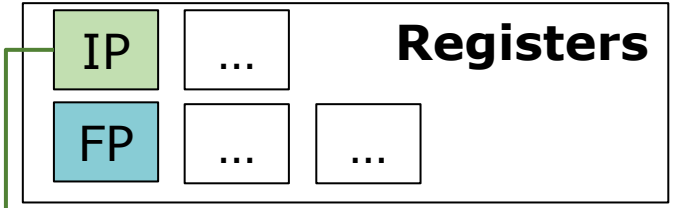

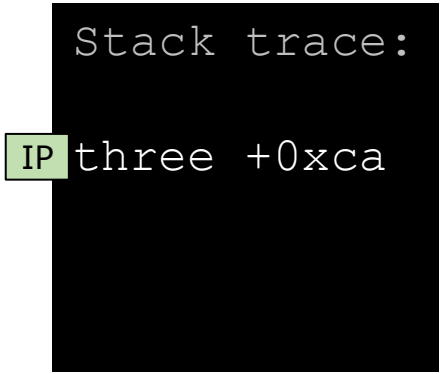


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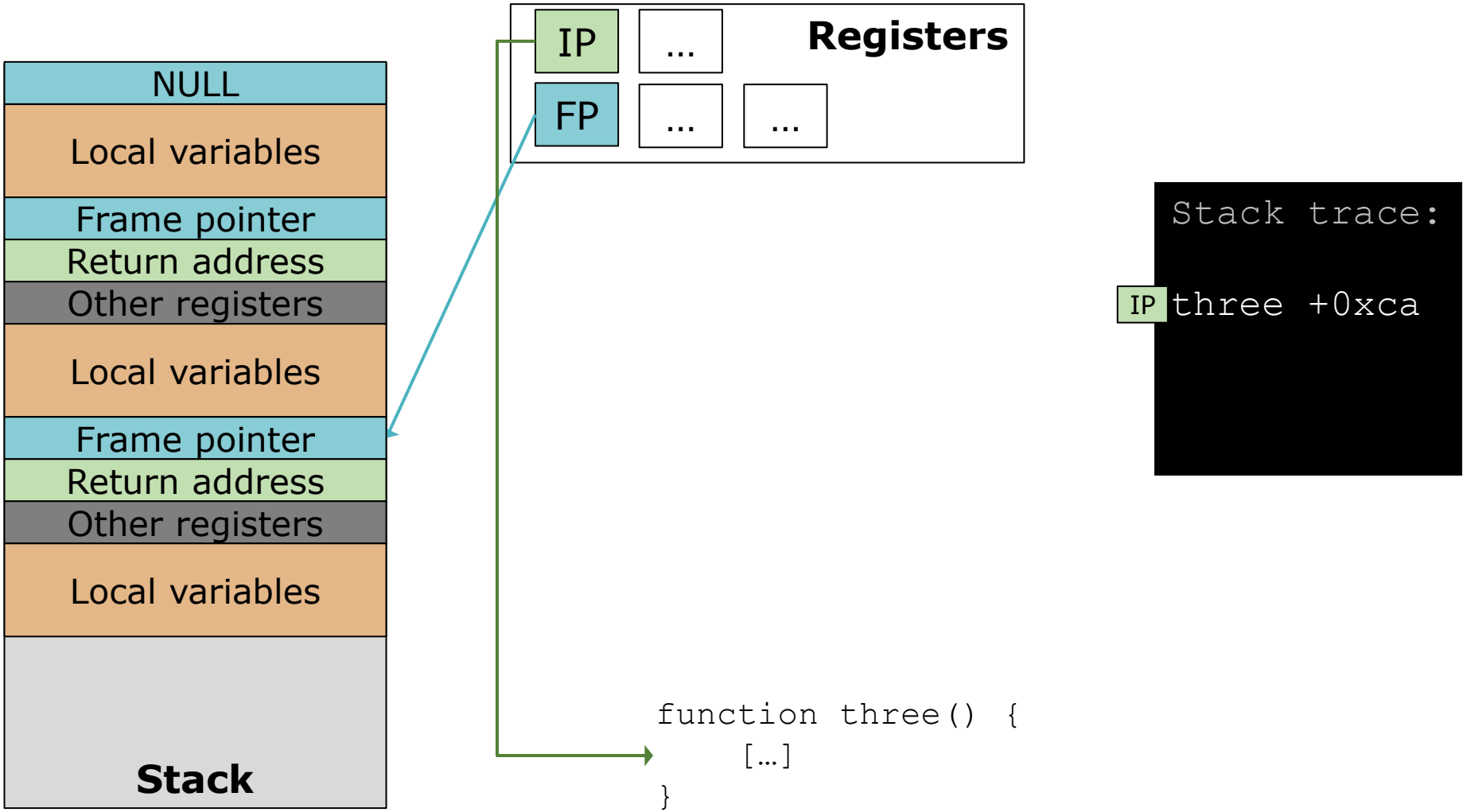

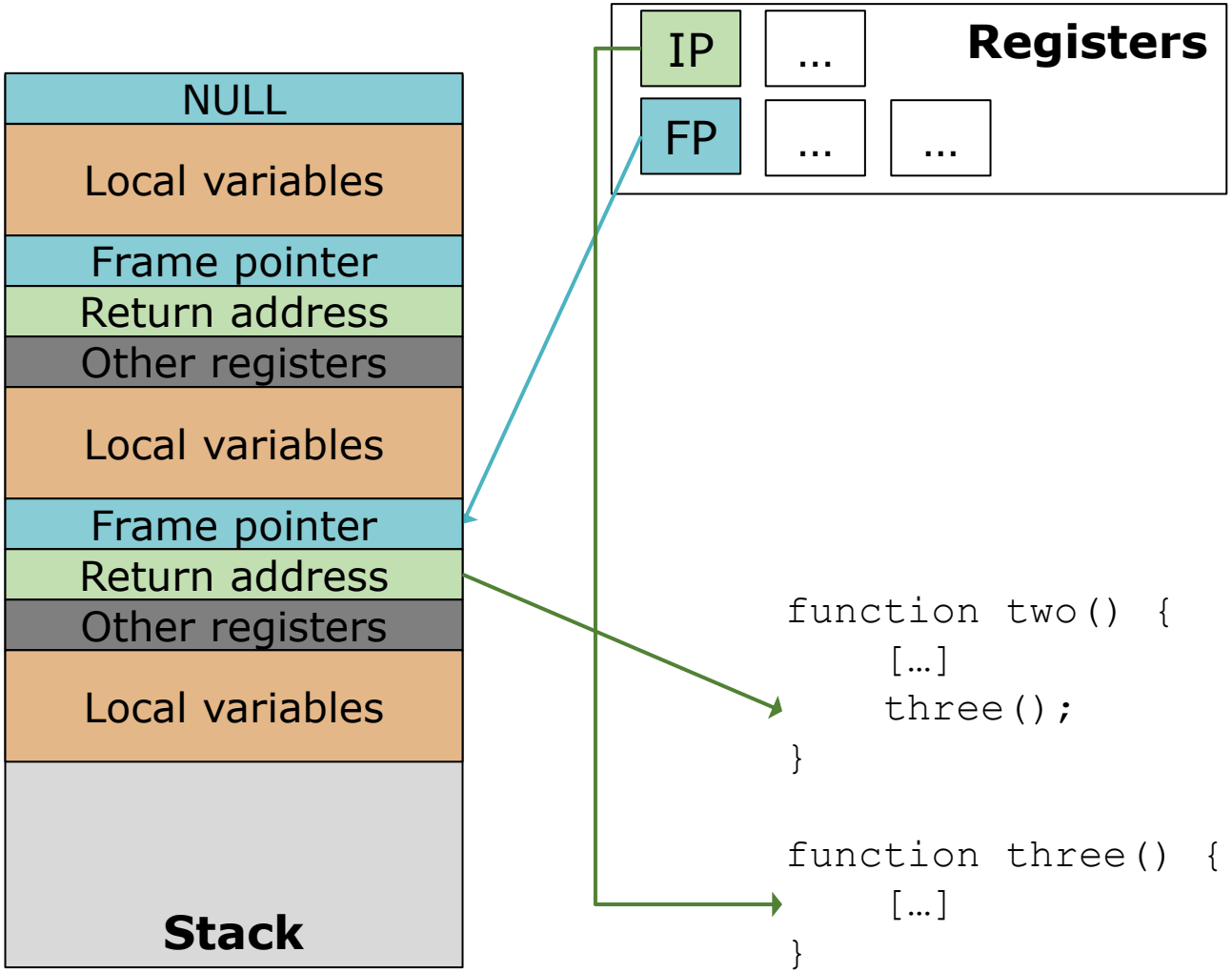

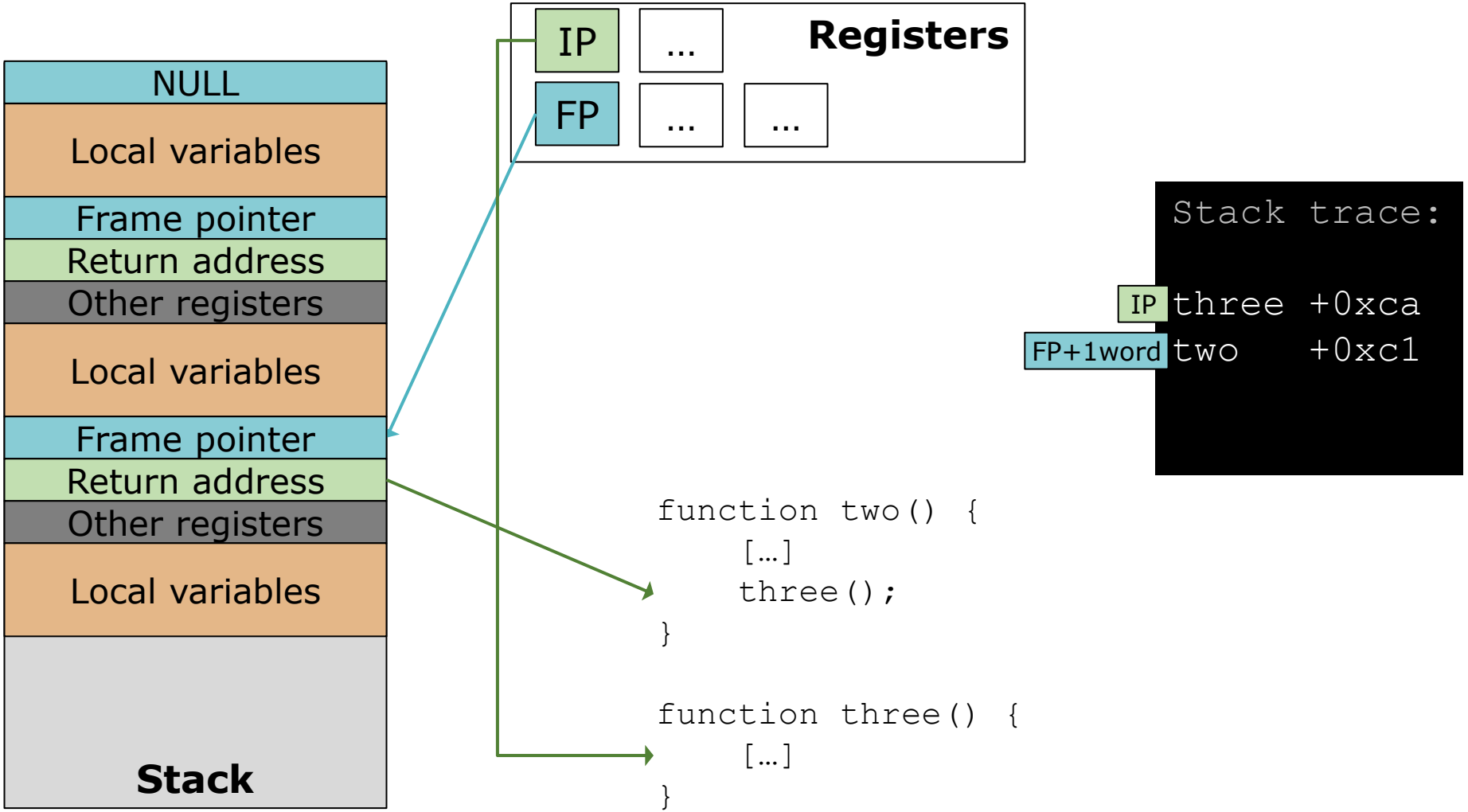

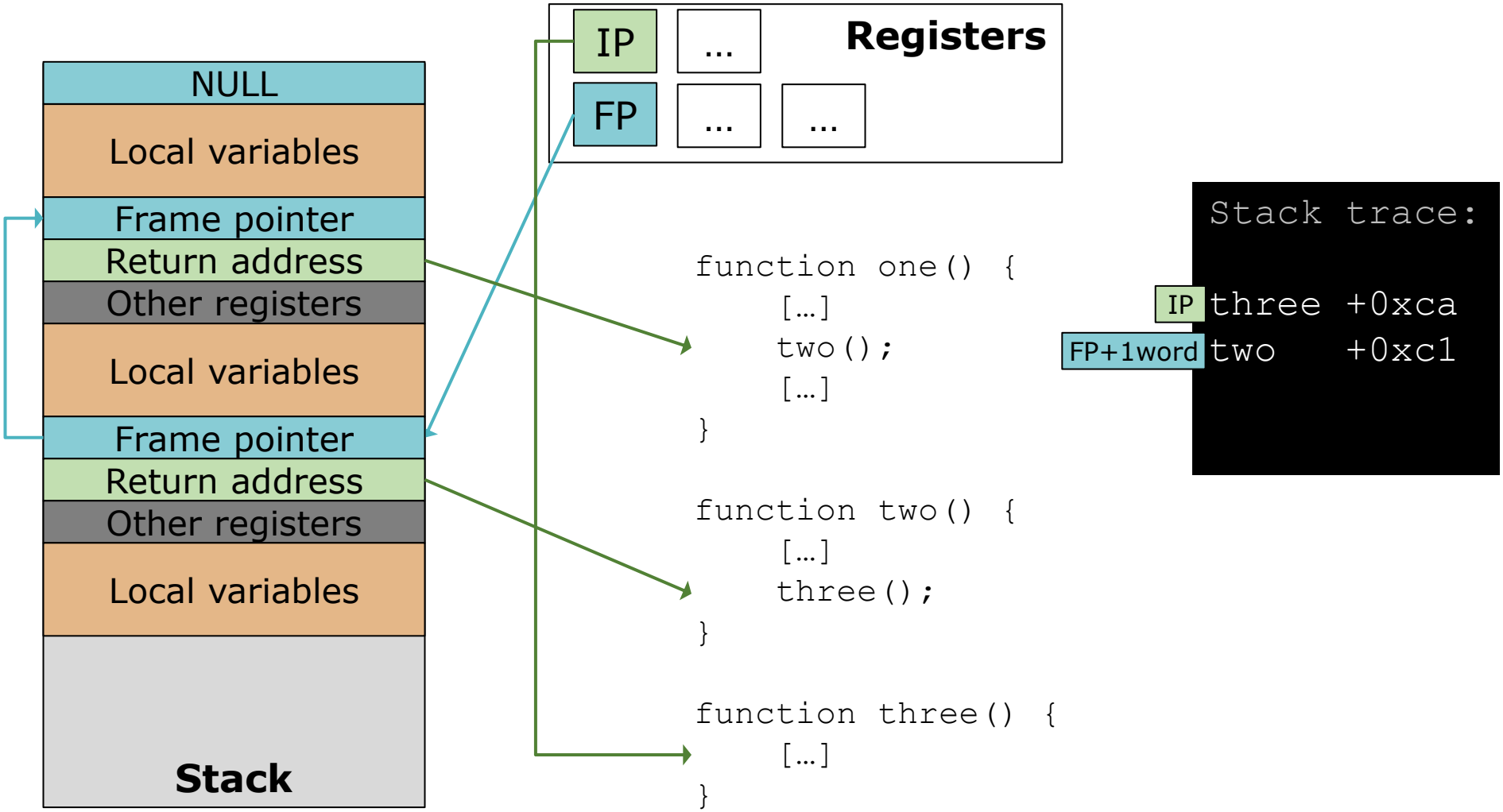

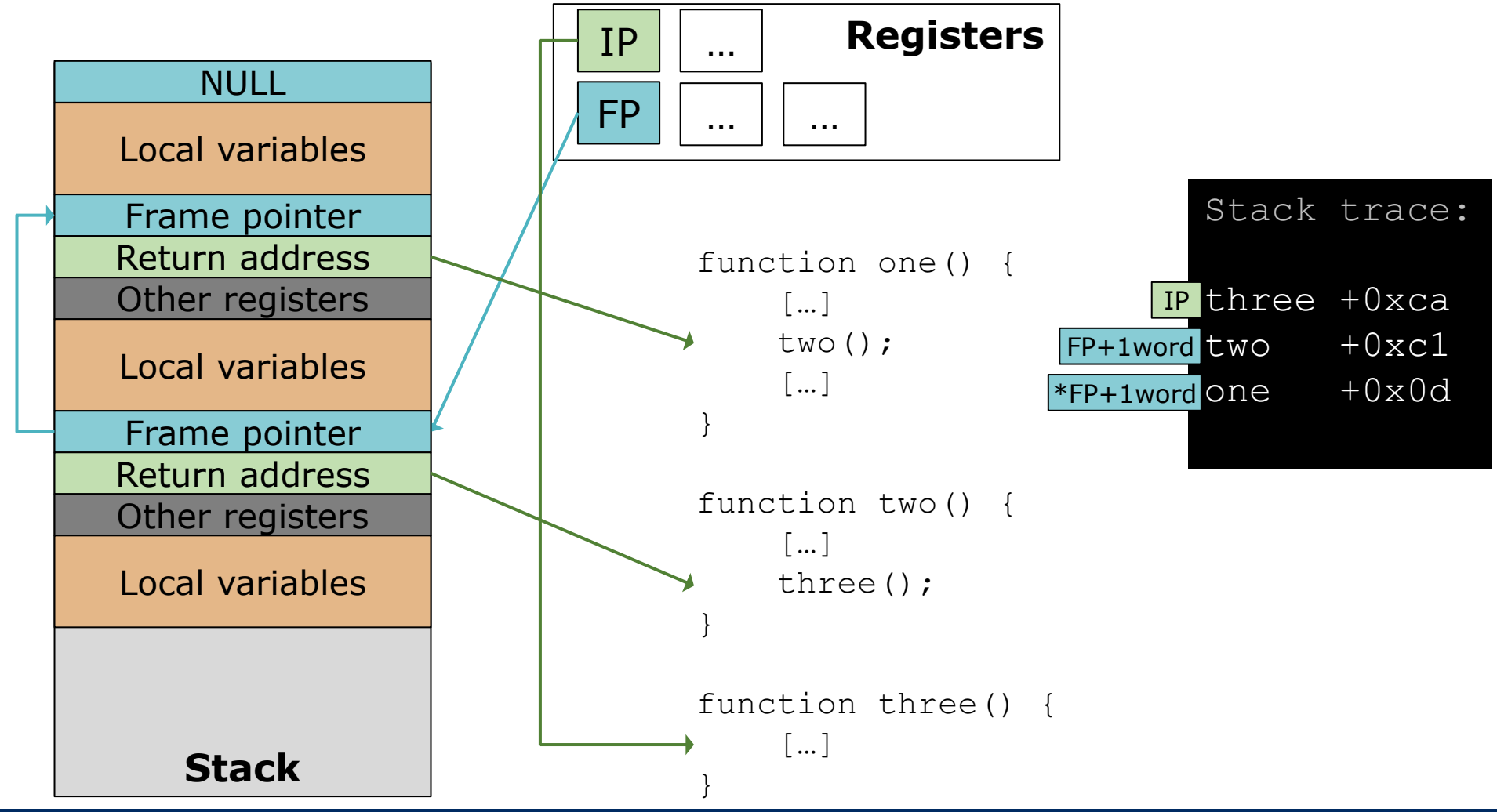

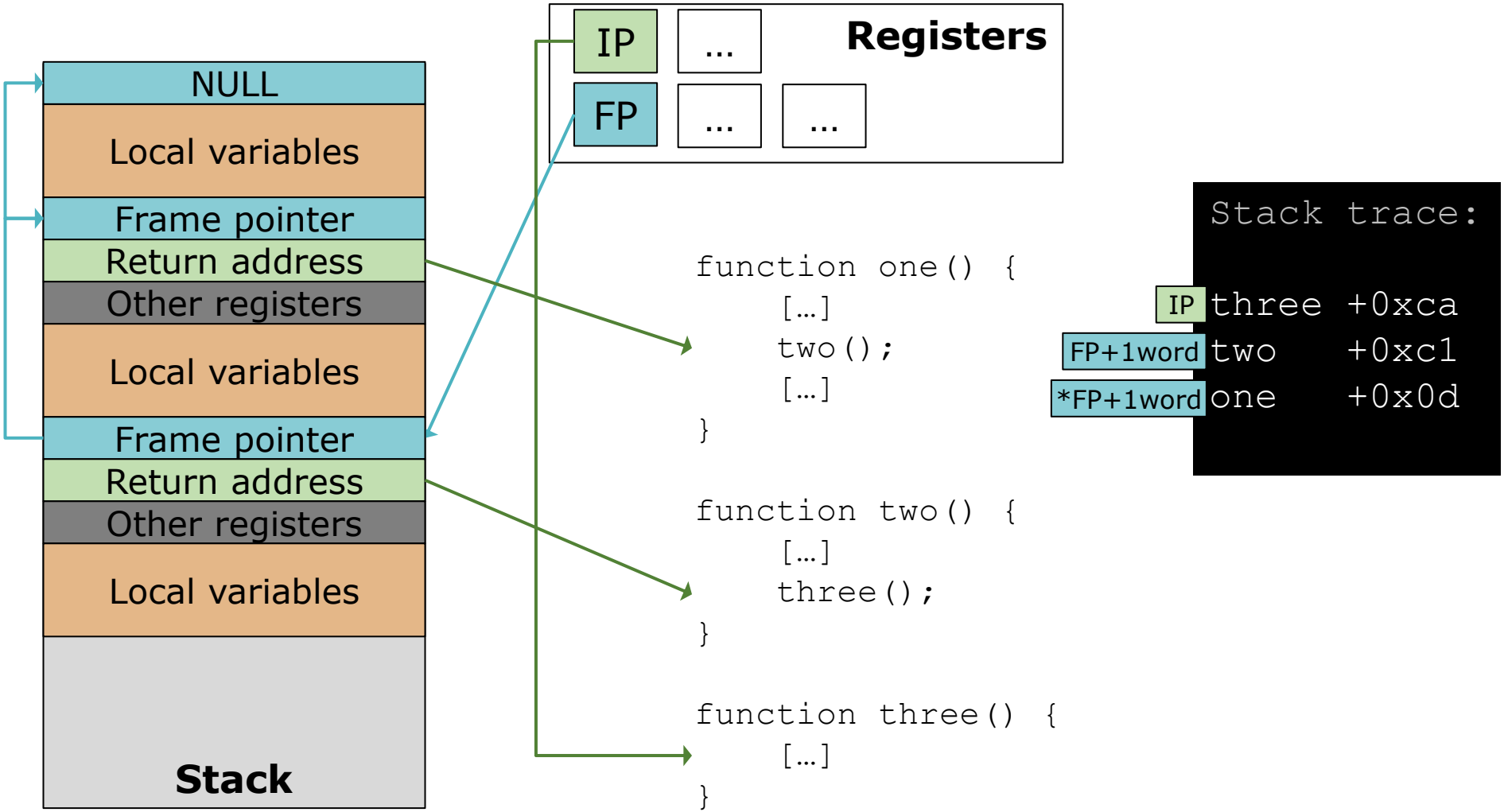

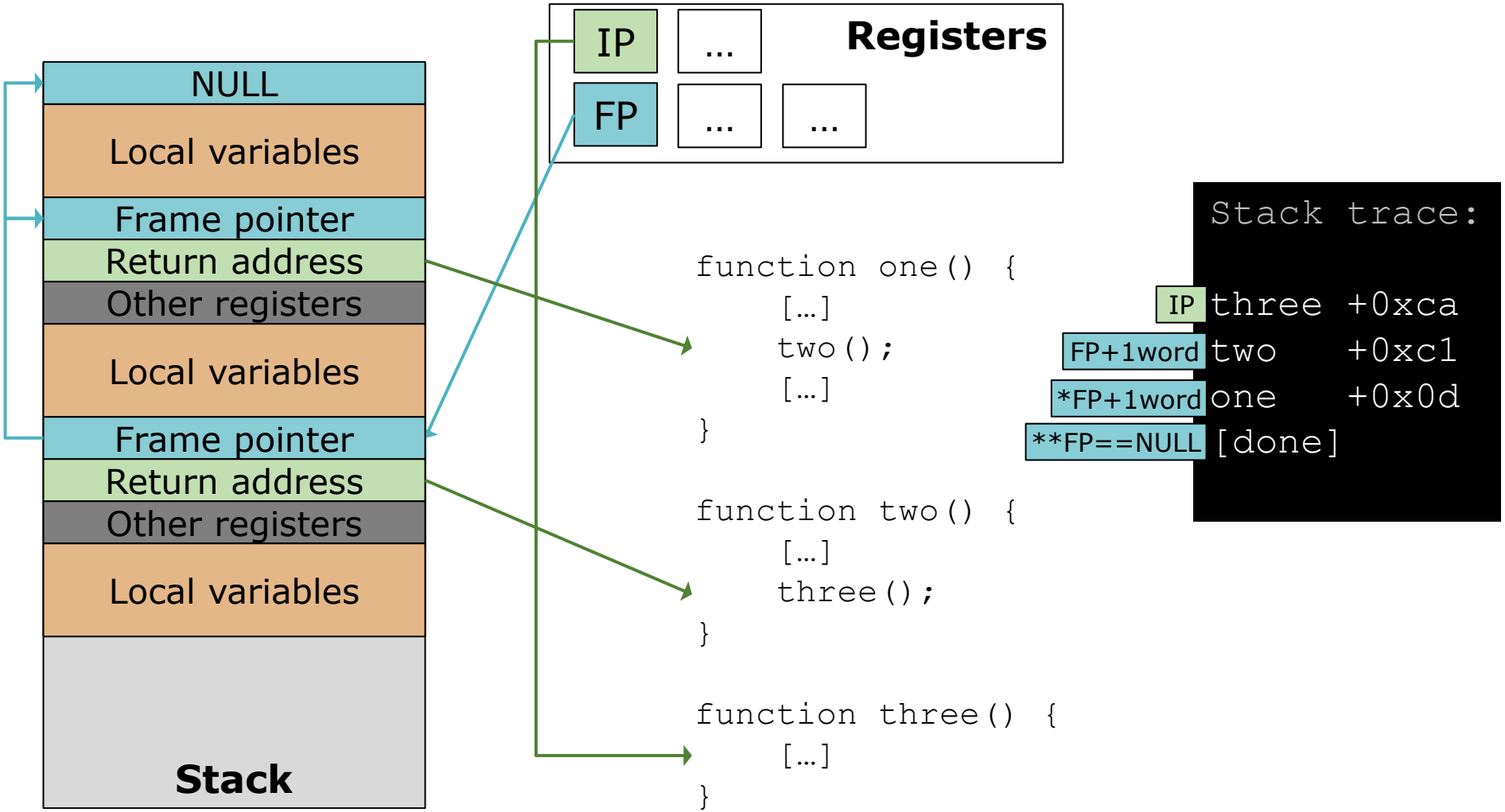

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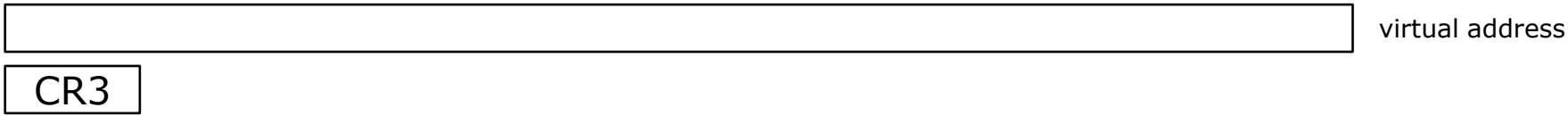

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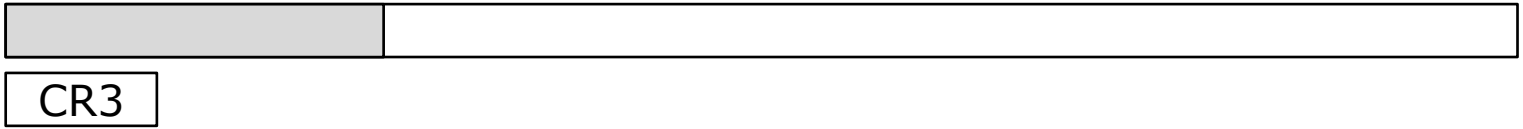

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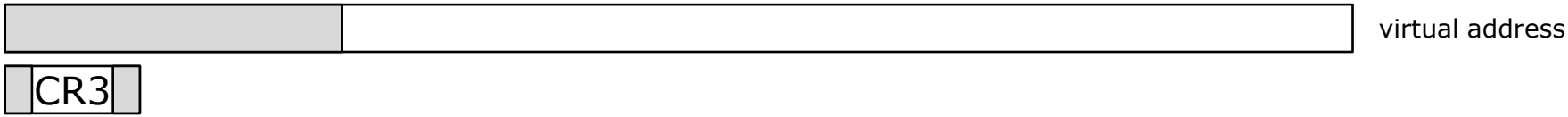

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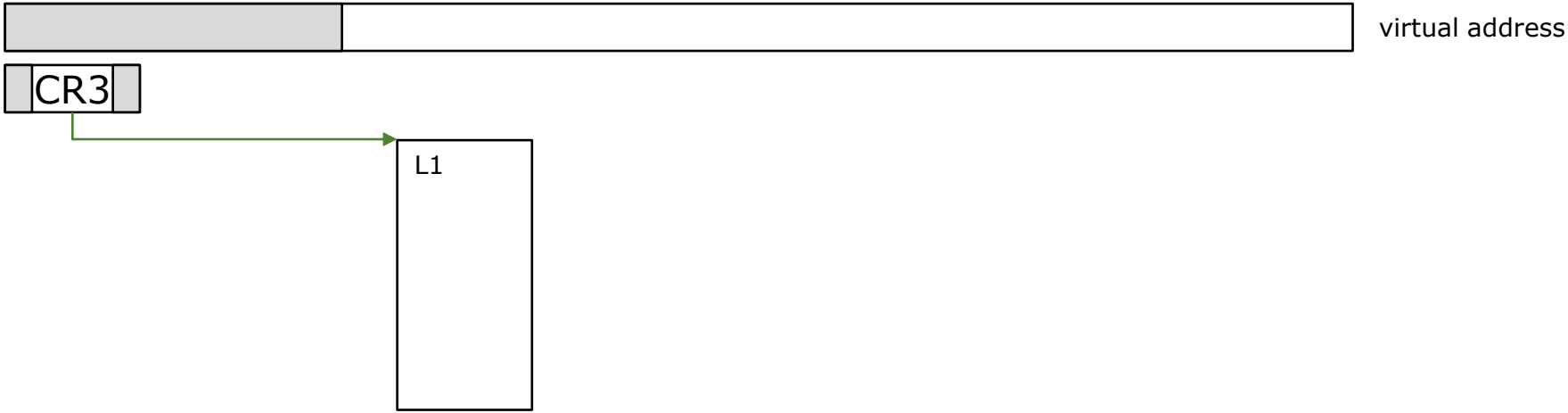

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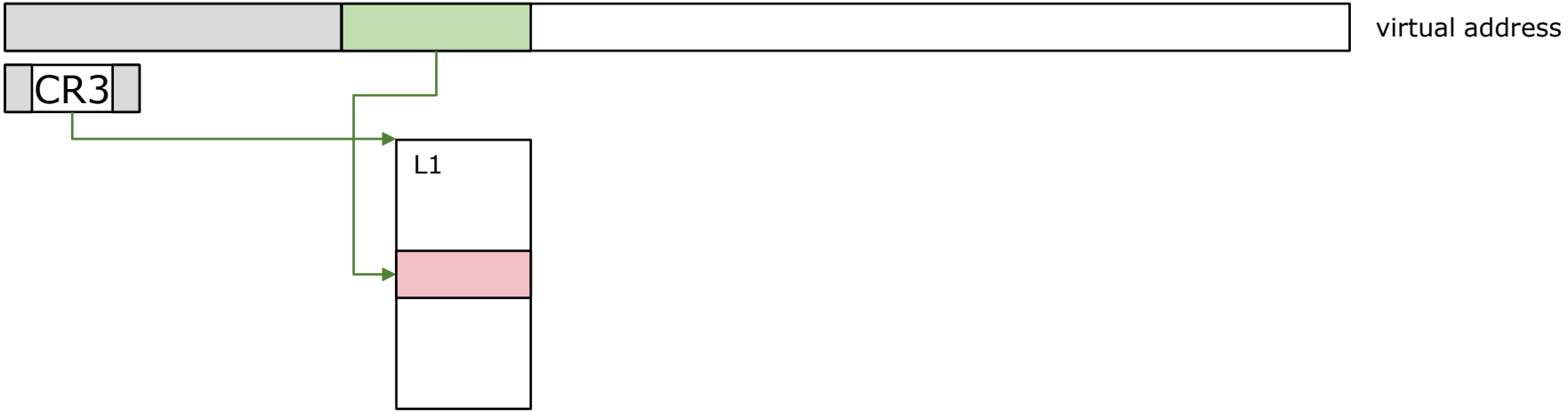

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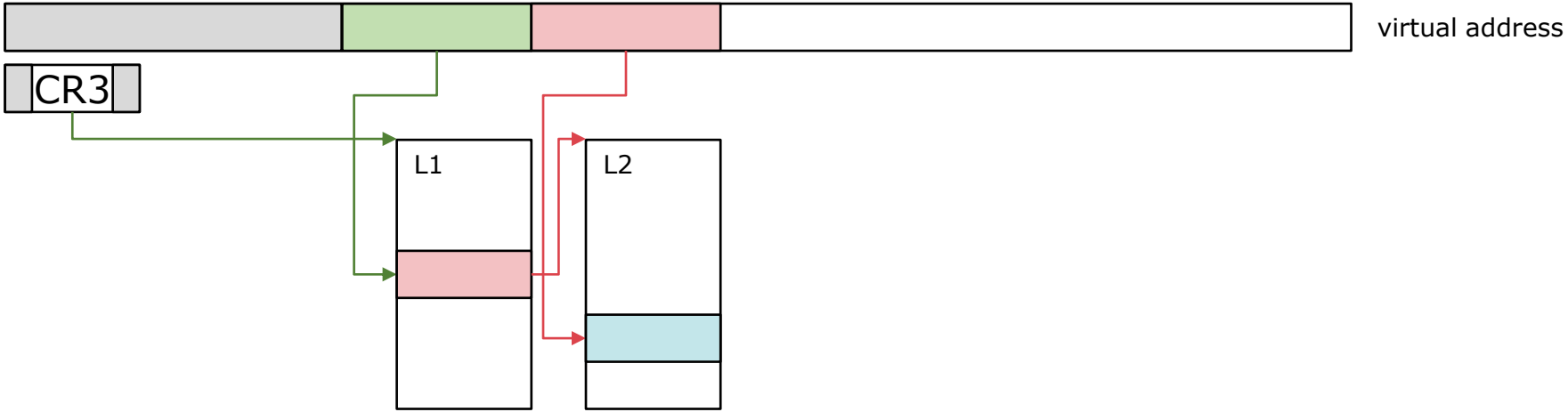

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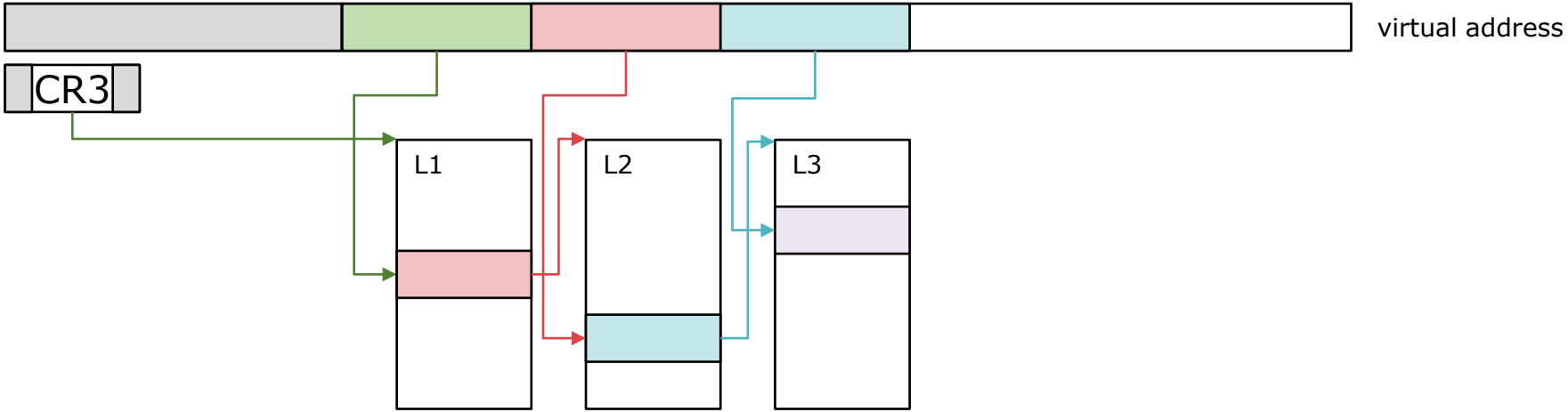

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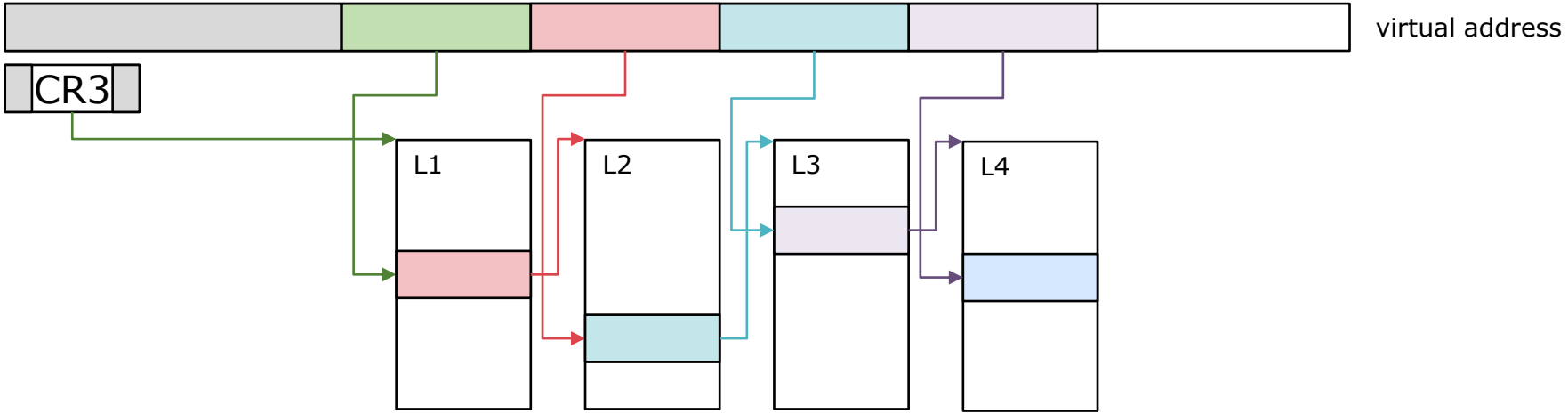

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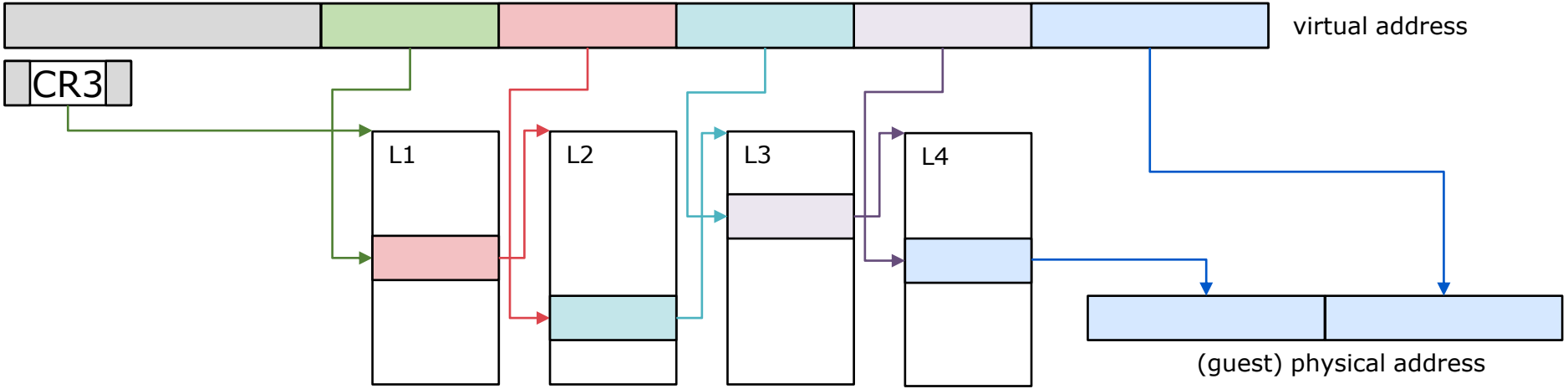

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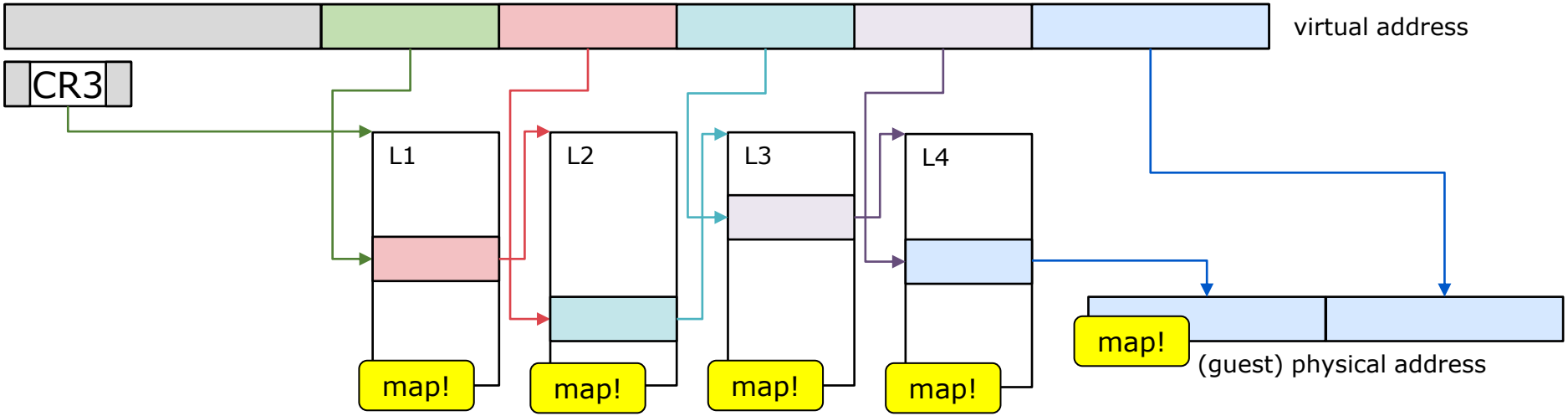

So many maps:

- 5 per entry * stack depth

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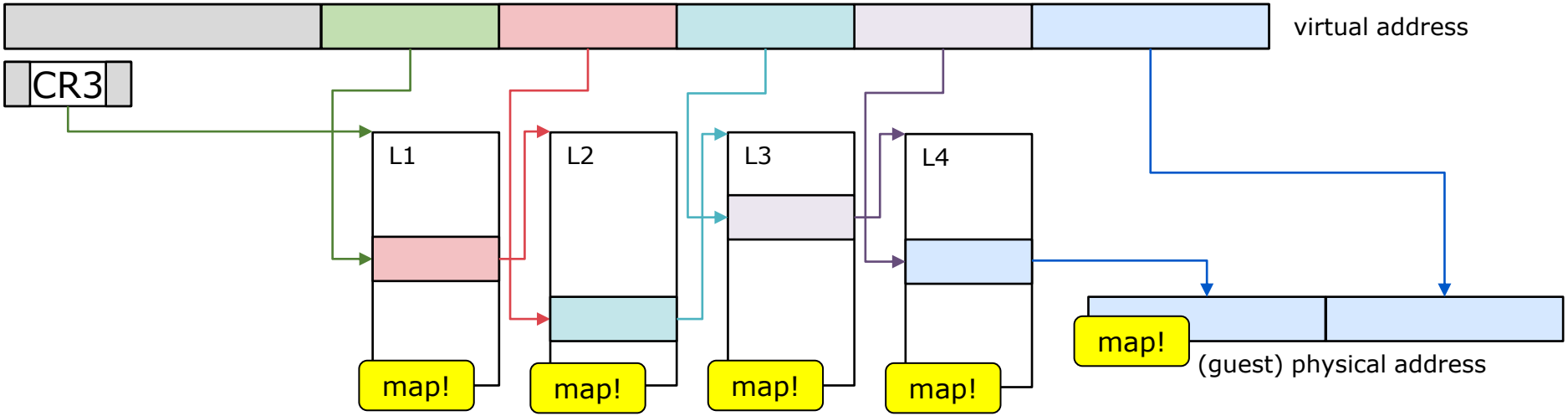

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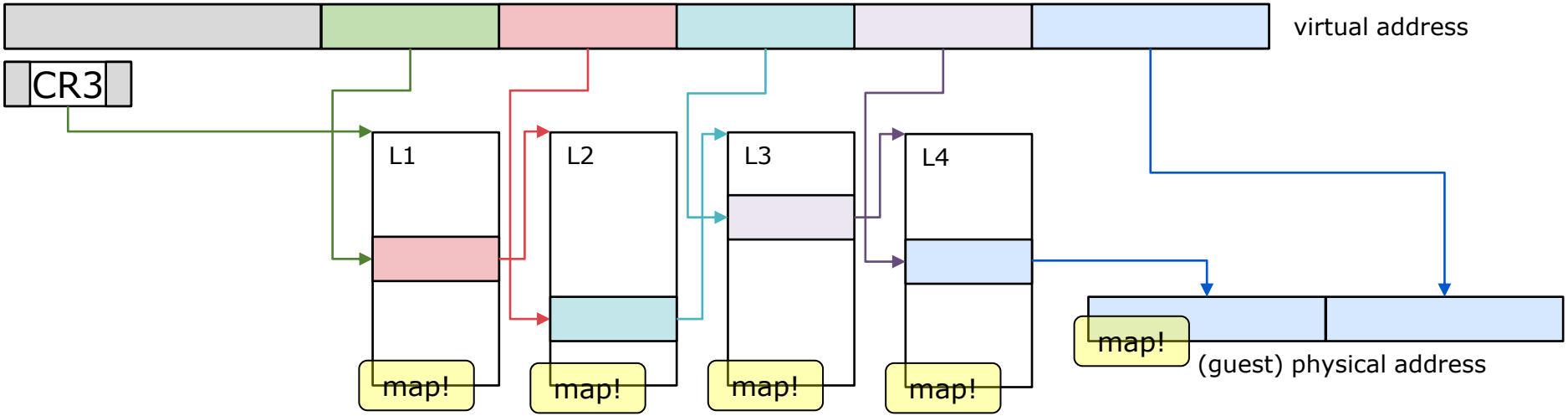

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Needs unstripped binary

- You're welcome to strip it afterwards

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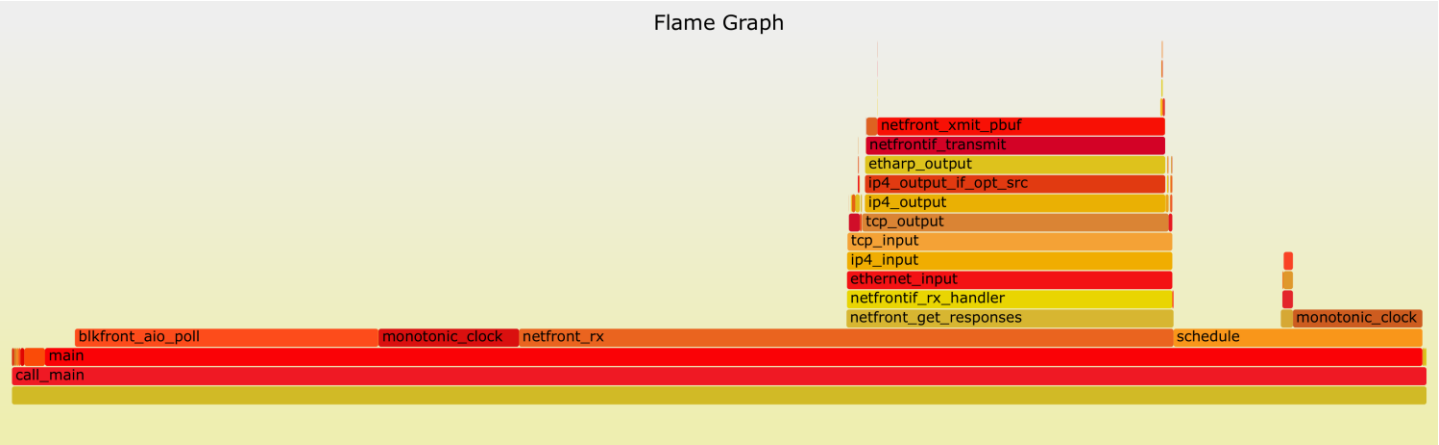

https://github.com/brendangregg/flamegraph

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- X Axis: relative run time
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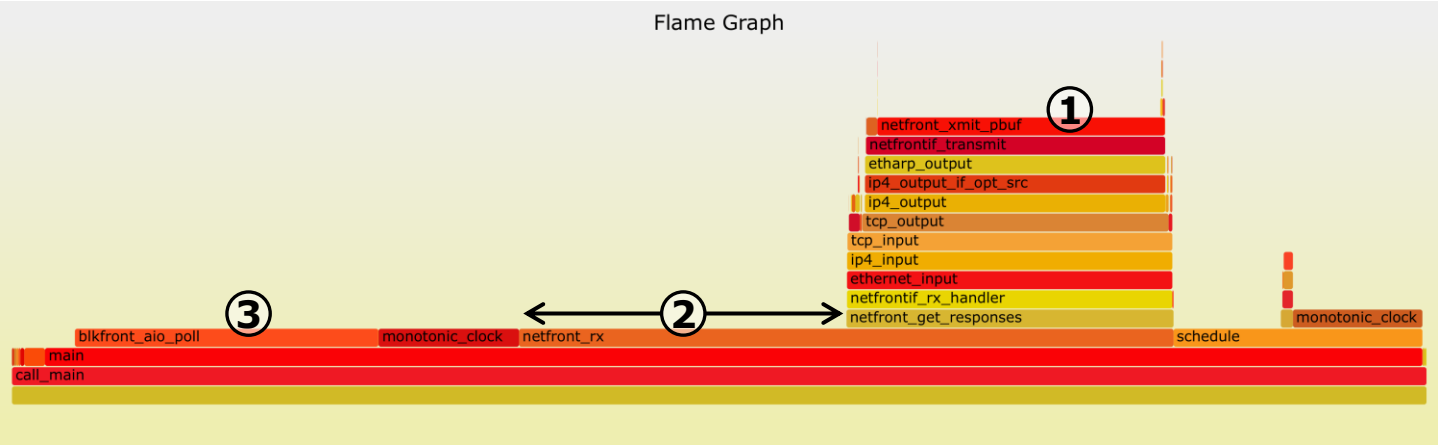

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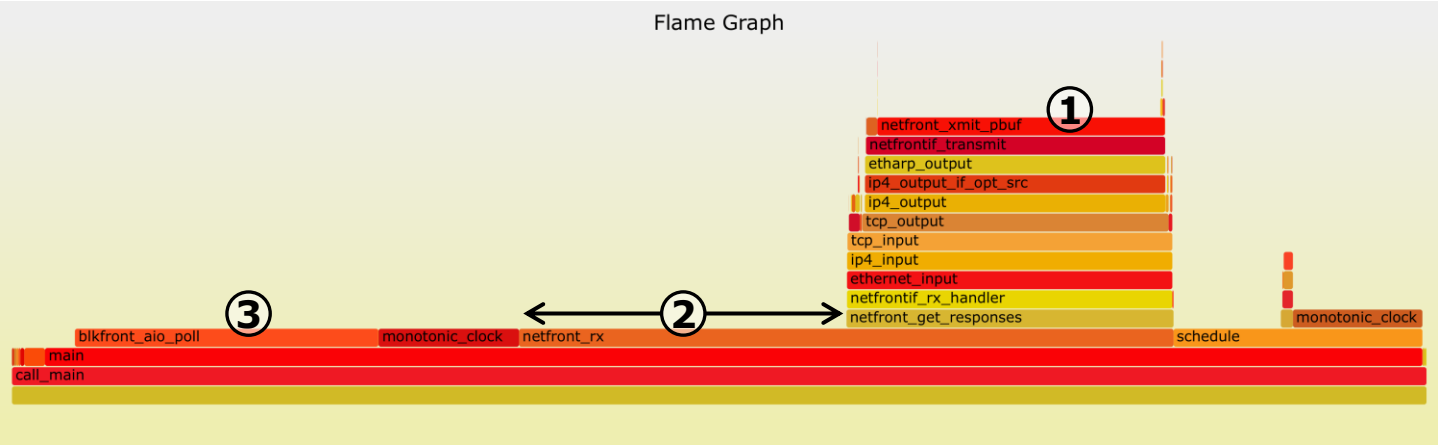

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Yep, it’s a MiniOS* doing network communication

*with lwip for TCP/IP

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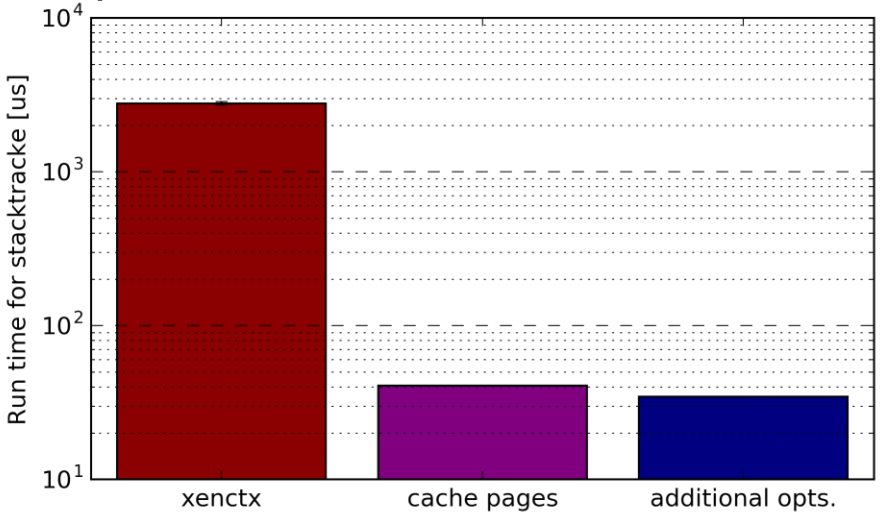

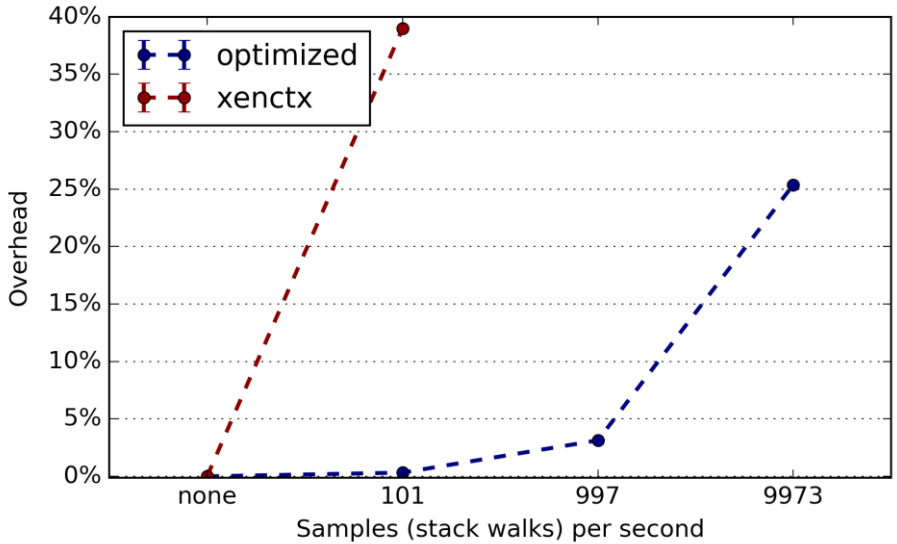

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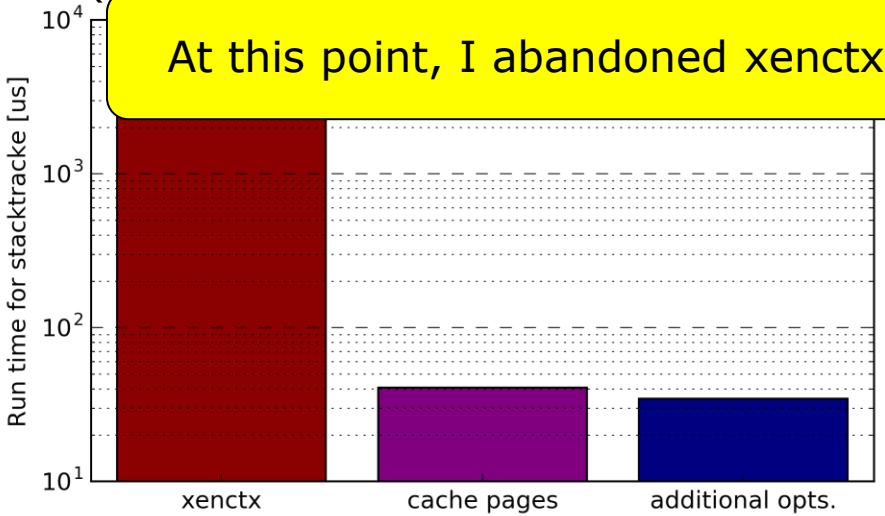
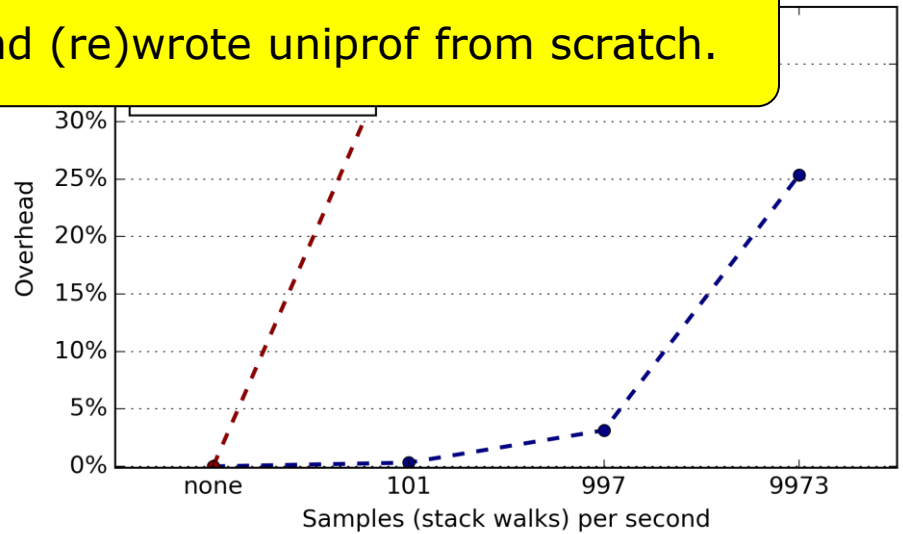
At this point, I abandoned xenctx and (re)wrote uniprof from scratch.





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  - Xen 4.7 introduced low-level libraries (libxencall, libxenforeigmemory)
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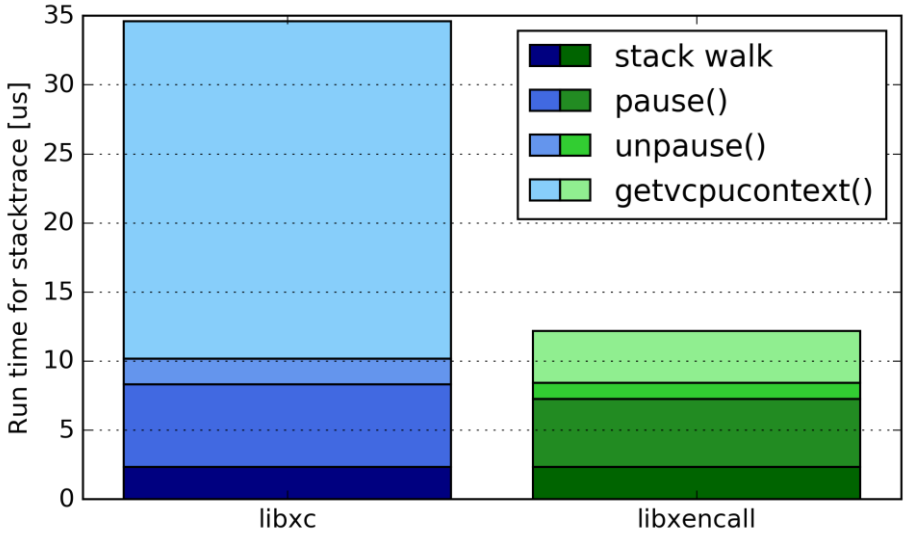
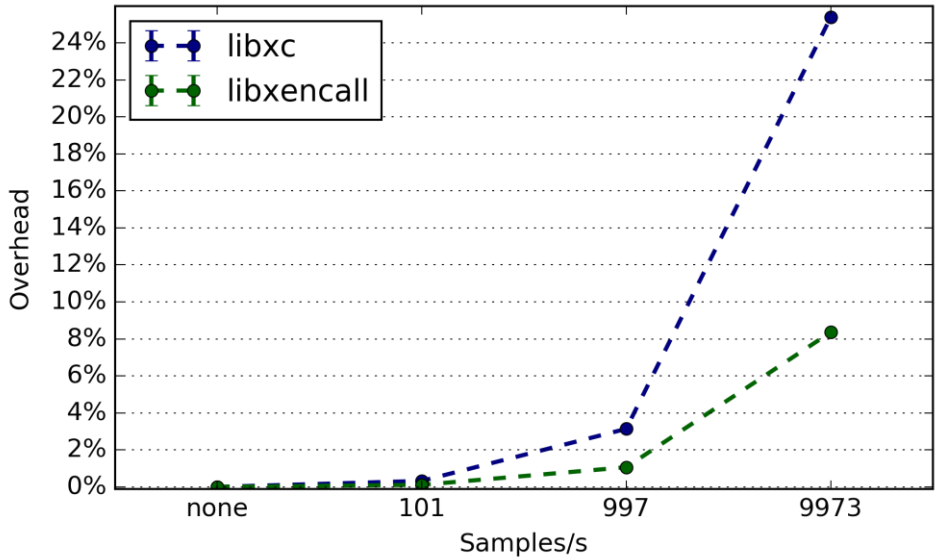
- 100-fold improvement is nice! But we can do better:
  - Xen 4.7 introduced low-level libraries (libxencall, libxenforeigmemory)
  - Another significant reduction by ~ factor of 3
- End result: overhead of ~0.1% @101 samples/s





Performance on ARM

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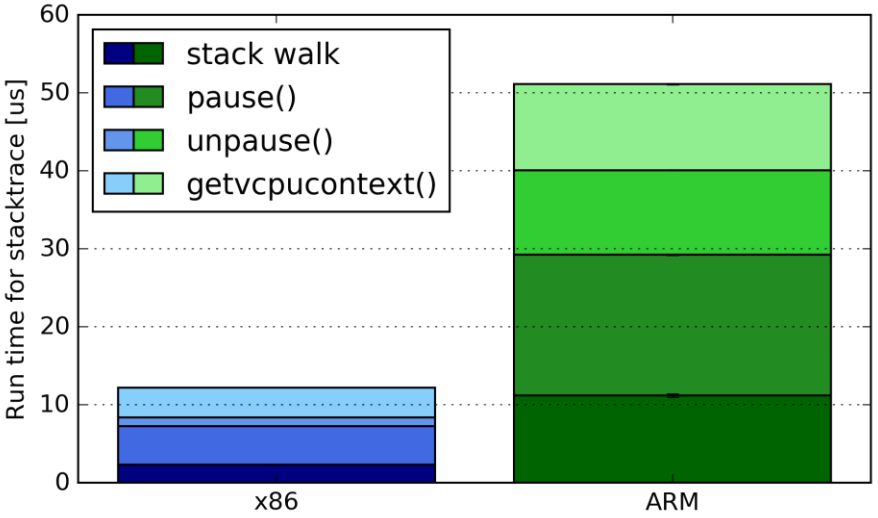
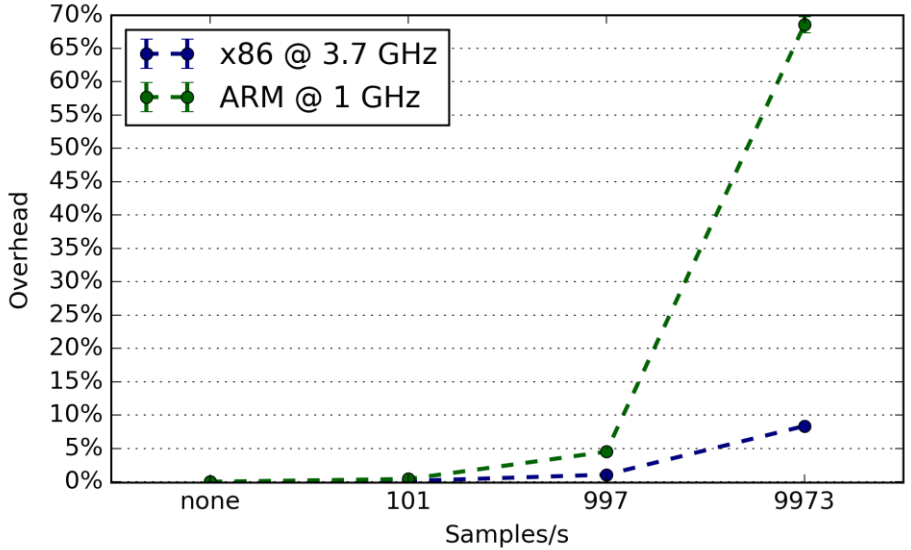
Performance on ARM

- uniprof supports ARM (xenctx doesn't)
  - Main challenge: different page table design
- ARM: much slower, overhead higher
  - But the CPU is much slower, too (Intel Xeon @3.7GHz vs. Cortex A20 @1GHz)
  - So fewer samples/s needed for same effective resolution





No Frame Pointer? No Problem!

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But we can do without FPs

- Use stack unwinding information
  - It’s already included if you use C++ (for exception handling)
  - It doesn’t change performance
  - Only binary size
- DWARF standard

```
$ readelf -S <ELF>
There are 13 section headers, starting at offset 0x40d58:

Section Headers:
  [Nr] Name              Type             Address           Offset
       Size              EntSize          Flags  Link  Info  Align
[...]
  [ 4] .eh_frame         PROGBITS         0000000000035860  00036860
       00000000000066f8  0000000000000000   A       0     0     8
  [ 5] .eh_frame_hdr     PROGBITS         000000000003bf58  0003cf58
       000000000000128c  0000000000000000   A       0     0     4
[...]
```

Unwinding without Frame Pointers

- How does it work?

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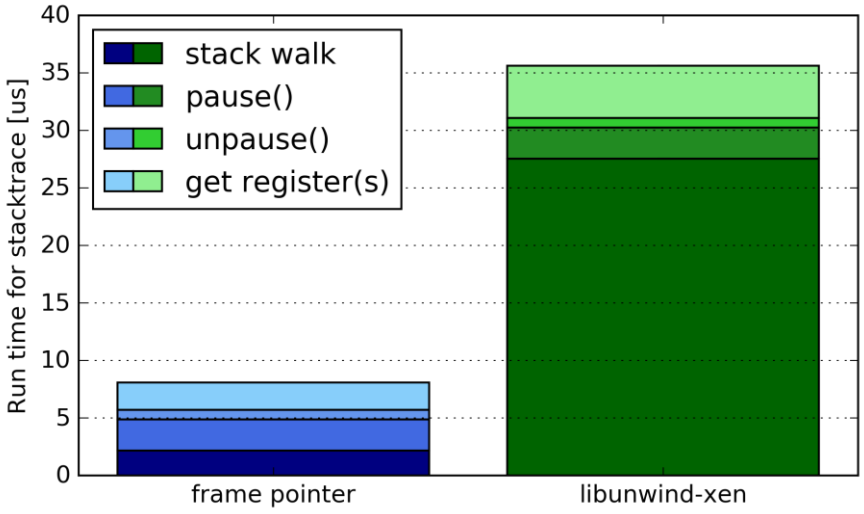
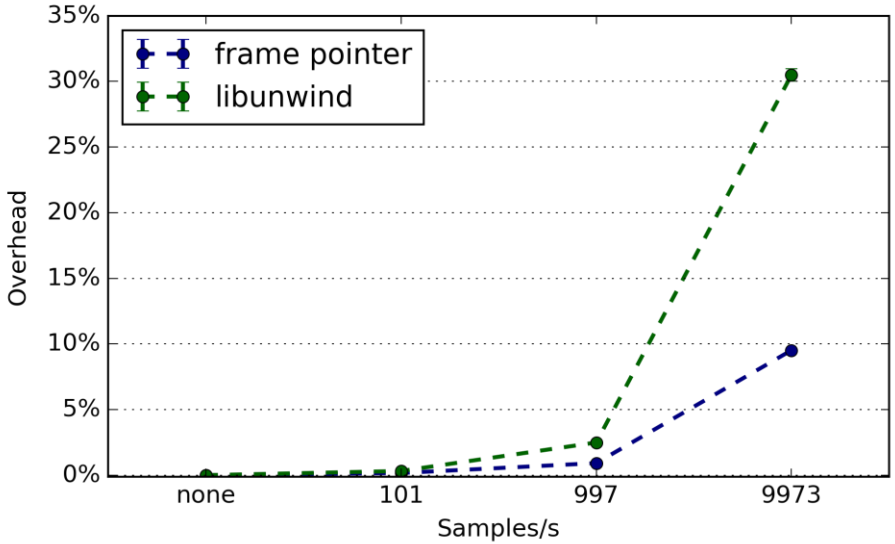
Several library implementations

- uniprof uses libunwind
- Actually, a libunwind patched for Xen guest introspection support
- Might be useful for other tools?

Performance: uniprof w/ libunwind

- Performance lower than with frame pointer
  - Reason: libunwind does more than we need (full register reconstruction etc.)
- Different library or own implementation promising
  - But "good enough" for many cases
  - And a good area for future work





Thank you!

Questions?

uniprof: https://github.com/cnplab/uniprof
libunwind-xen: https://github.com/cnplab/libunwind
FlameGraphs: https://github.com/brendangregg/flamegraph