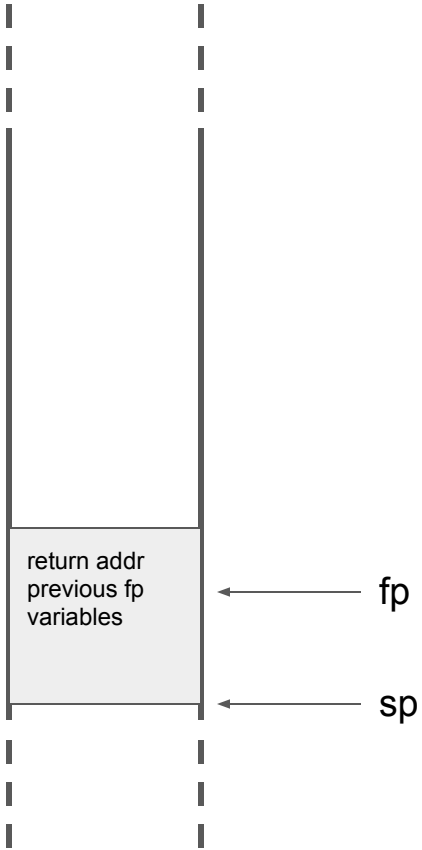
sframes

Getting full user space stack trace

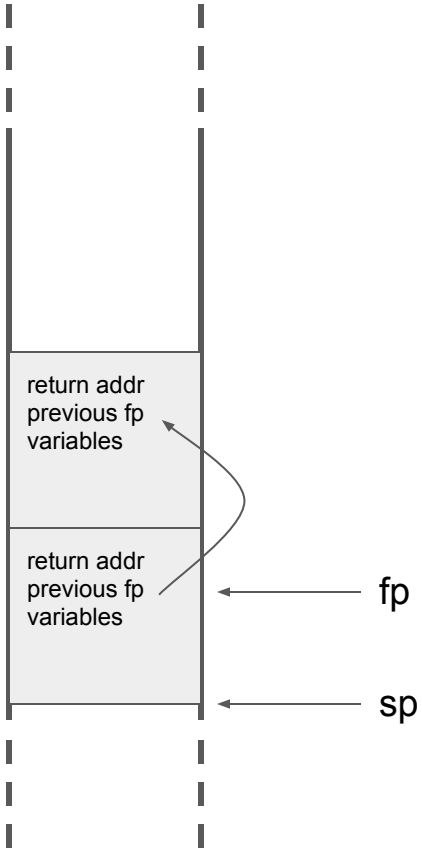
Acquiring user space stack traces

- Currently requires frame pointers
  - Perf also copies large amounts of the user space stack trace
- Frame pointers require setup at each function
  - More instructions to execute
- Frame pointers require a register to use
  - Pressure on register use
- Overhead: https://lwn.net/Articles/919940/
  - Kernel build: 2.4% increase
  - Blender test case: 2% increase
  - Python programs: Up to 10% increase!

Stack frames



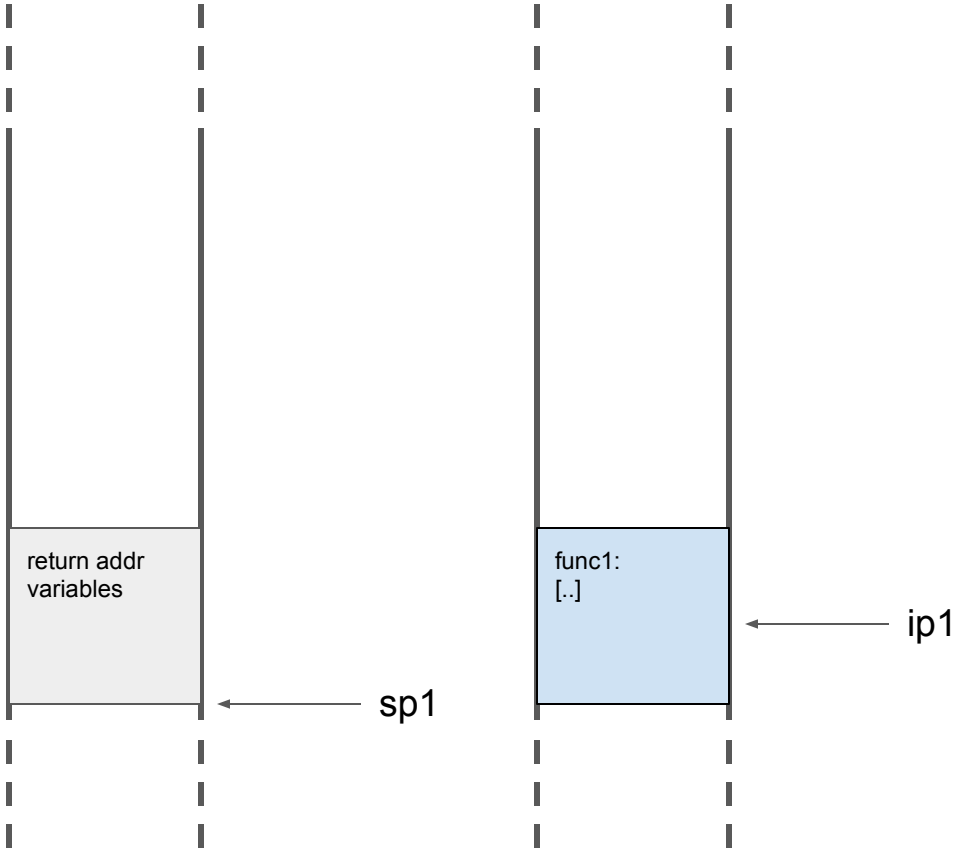
Stack frames



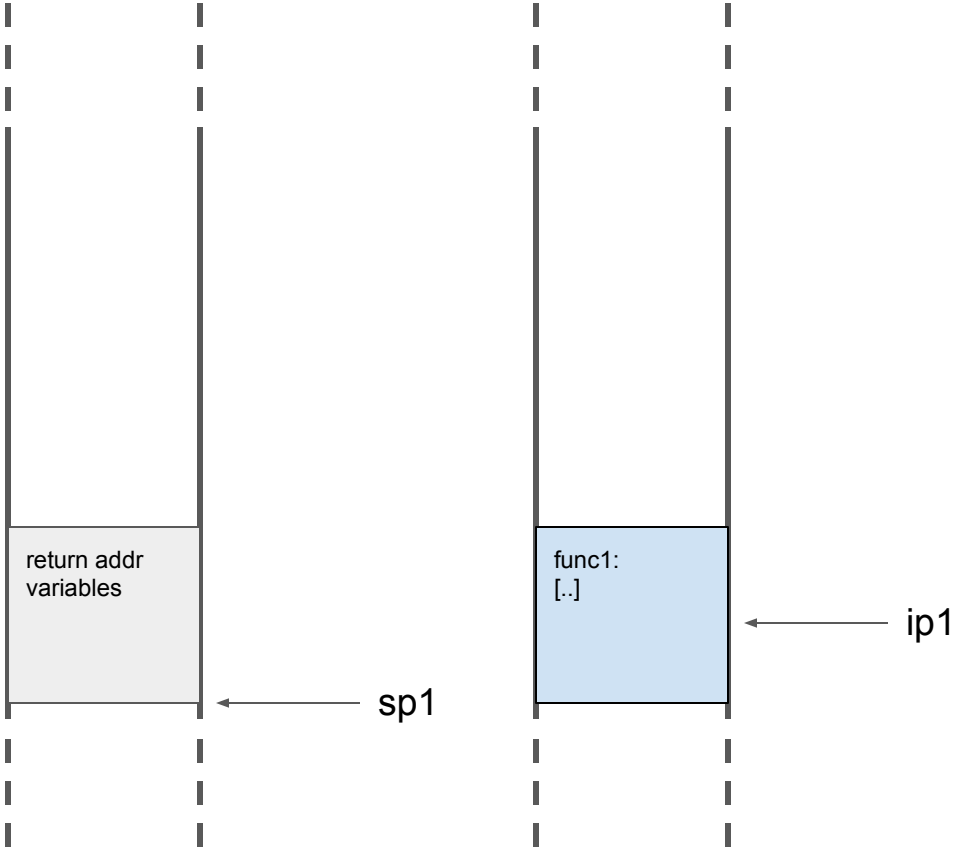
The Orc Unwinder

- Oops Rewind Capability
  - Needs something to go with DWARF and ELF formats!
- Much simpler than DWARF
  - Fewer and simpler annotations in the kernel asm files
  - Fewer bugs as a result (I know my DWARF annotations were very buggy)
- Added in 4.14 or live kernel patching
  - Live patching needed a reliable stack trace
- Created with tools/`objtool` at compile time
- Uses two tables
  - `orc_unwind` - orc_entry structures
  - `orc_unwind_ip` - IP addresses in the same offset as the orc_entry structure

Orc frames

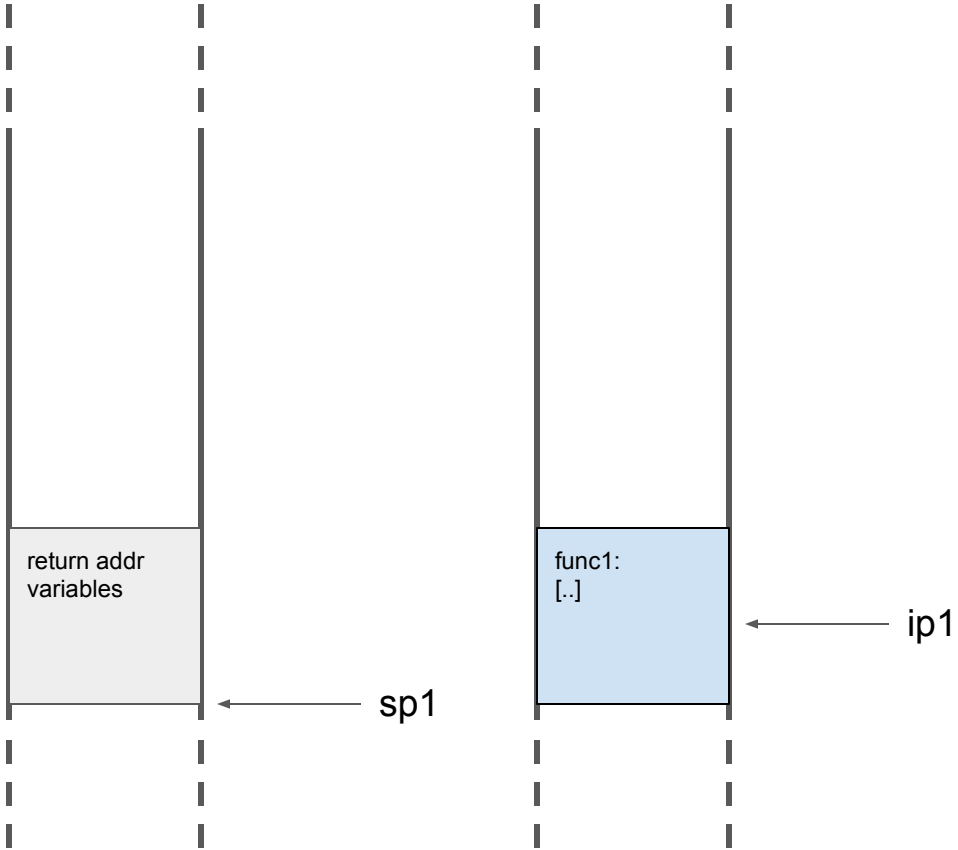


Orc frames



orc_unwind_ip:
[..]
ip1
[..]

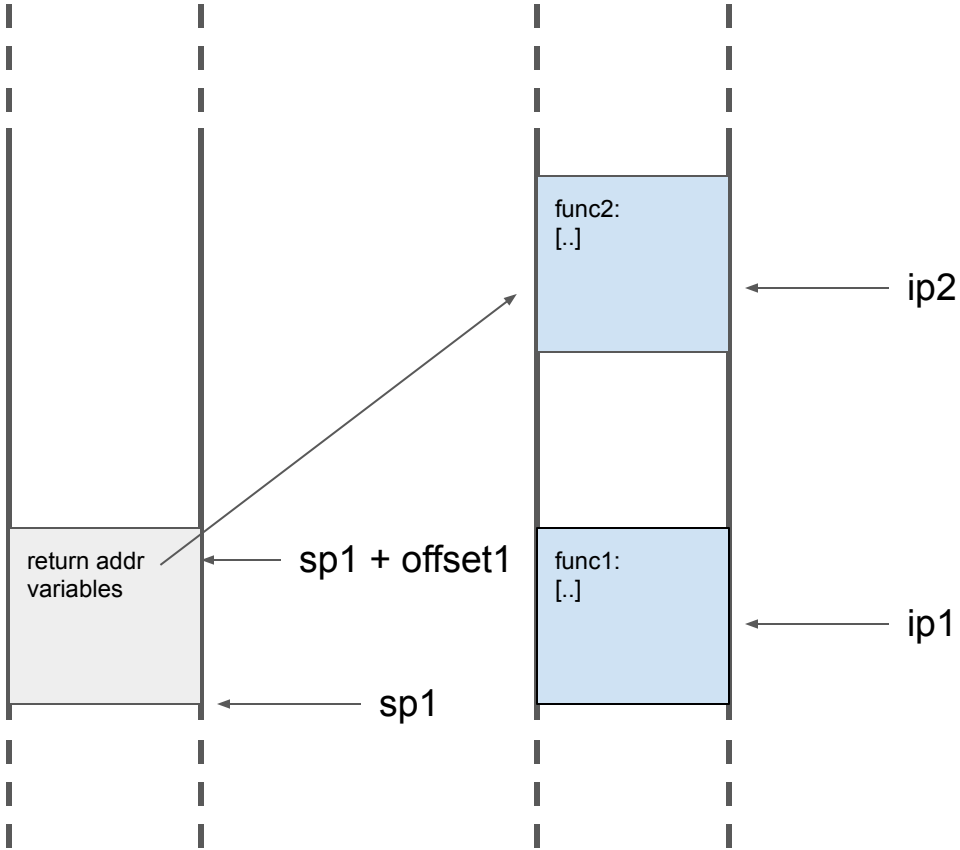
Orc frames



orc_unwind_ip:
[..]
ip1 →
[..]

orc_unwind:
[..]
entry1
    sp_offset = offset1
[..]

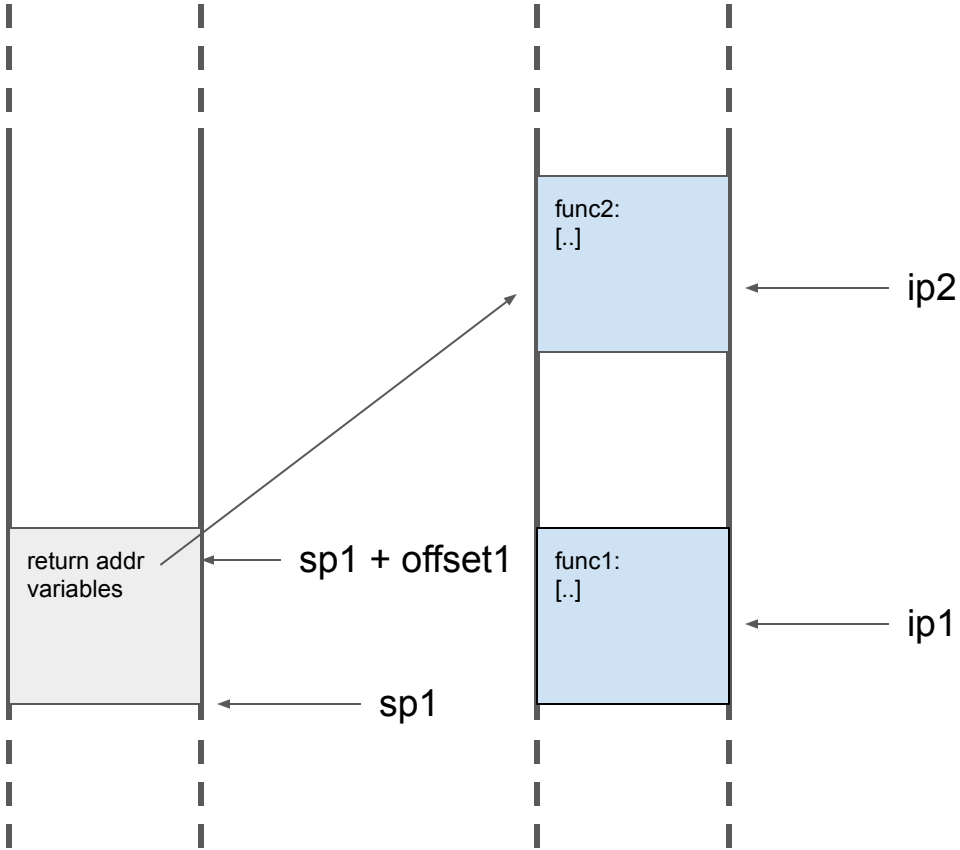
Orc frames



orc_unwind_ip:
[..]
ip1
[..]

orc_unwind:
[..]
entry1
sp_offset = offset1
[..]

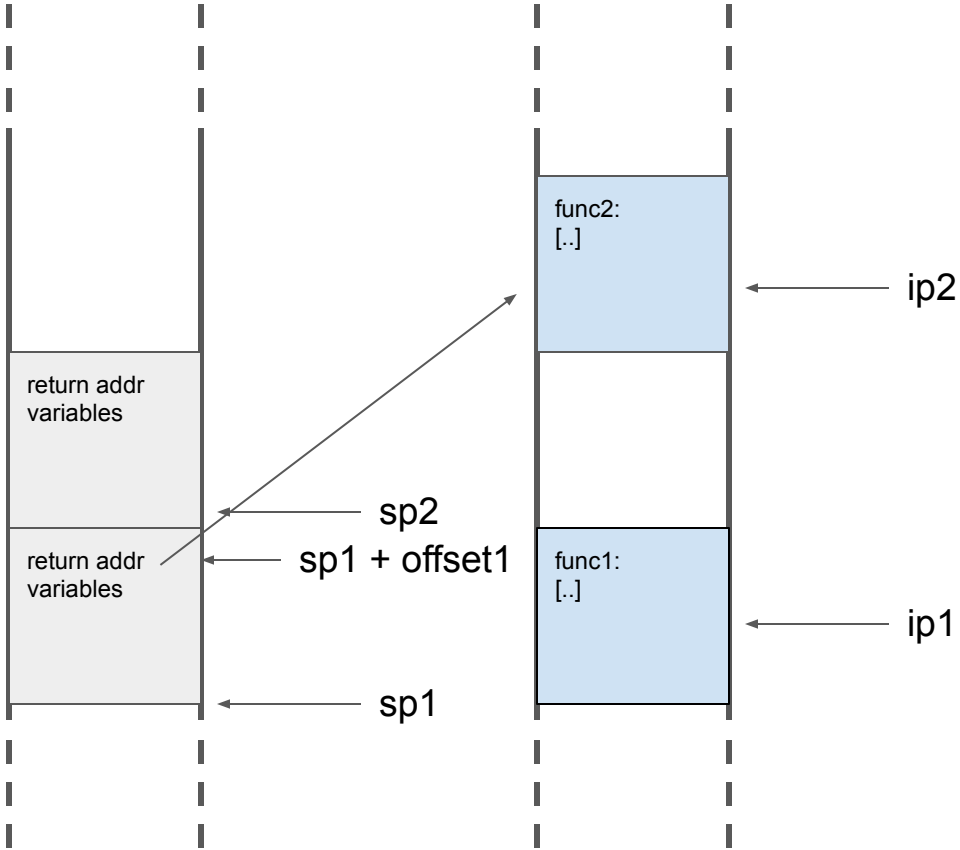
Orc frames



orc_unwind_ip:
[..]
ip1
[..]
ip2
[..]

orc_unwind:
[..]
entry1
sp_offset = offset1
[..]

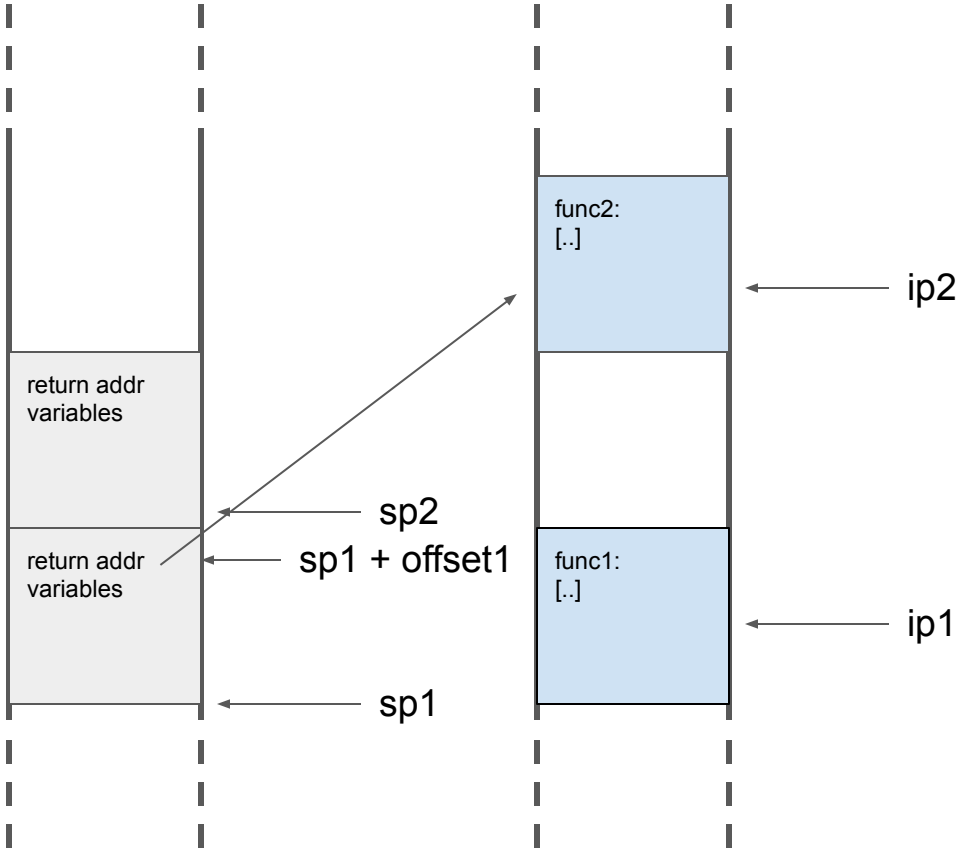
Orc frames



orc_unwind_ip:
[..]
ip1
[..]
ip2
[..]

orc_unwind:
[..]
entry1
sp_offset = offset1
[..]

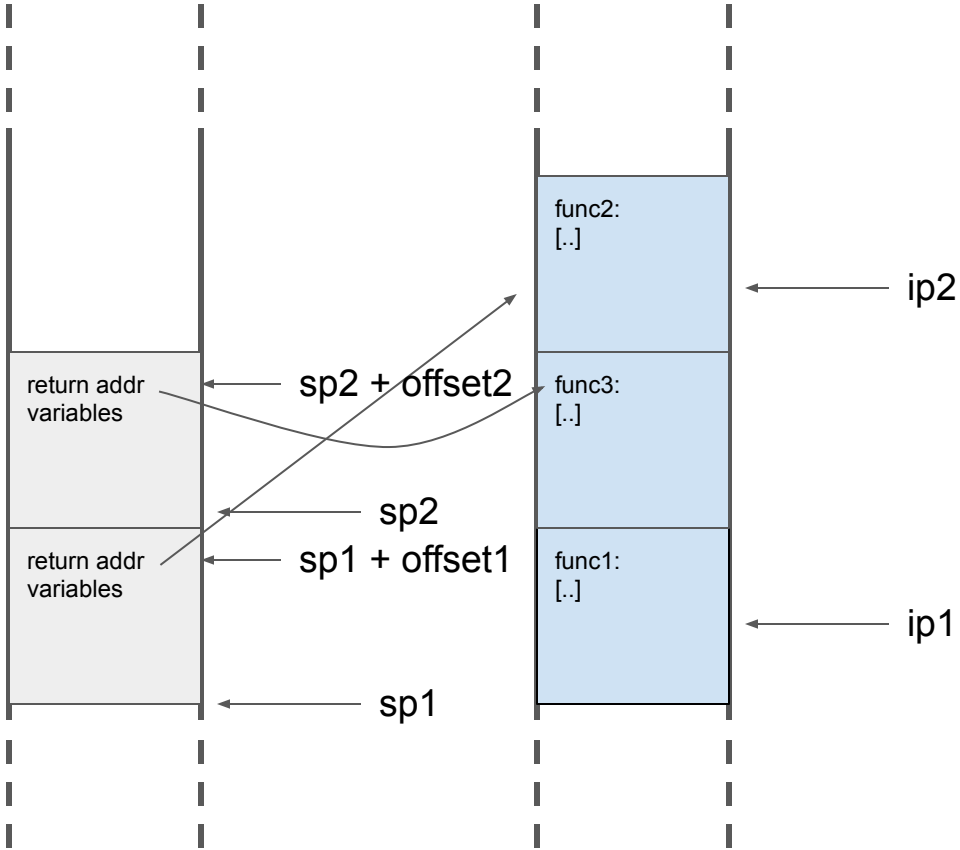
Orc frames




```
orc_unwind_ip:
[..]
ip1
[..]
ip2
[..]
```

```
orc_unwind:
[..]
entry1
    sp_offset = offset1
[..]
entry2
    sp_offset = offset2
[..]
```

Orc frames




```
orc_unwind_ip:
[..]
ip1
[..]
ip2
[..]
```

```
orc_unwind:
[..]
entry1
    sp_offset = offset1
[..]
entry2
    sp_offset = offset2
[..]
```

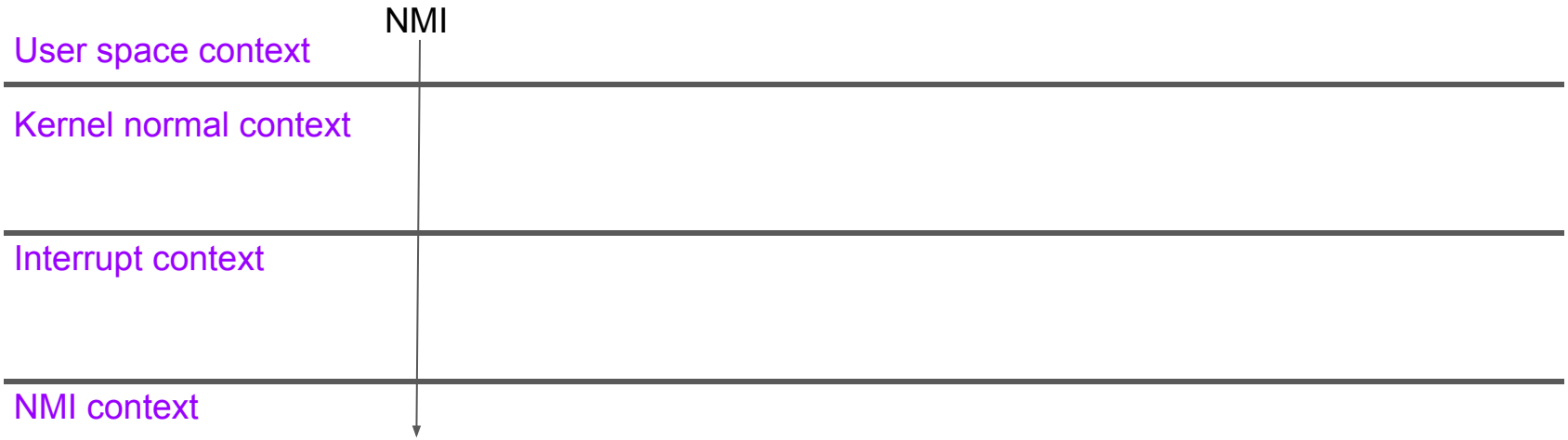
sframe

- sframe is based on orc, but for user space
- Can produce user space stack traces **without** frame pointers
- It is a section in the elf file with the two tables
- Requires to be compiled in and takes up disk space
- Can be read by the kernel
  - perf, ftrace and BPF can benefit from this

sframe in the kernel

- Can be done at the time of entering back into user space
  - The “ptrace” path
- Needs to handle offsets
  - Raw IP addresses are not helpful due to relocation
  - Can we convert them to the .text offset in the corresponding files?
- Perhaps even handle file names
  - Show not the address, but the `/proc/*/maps` info + offset into the file

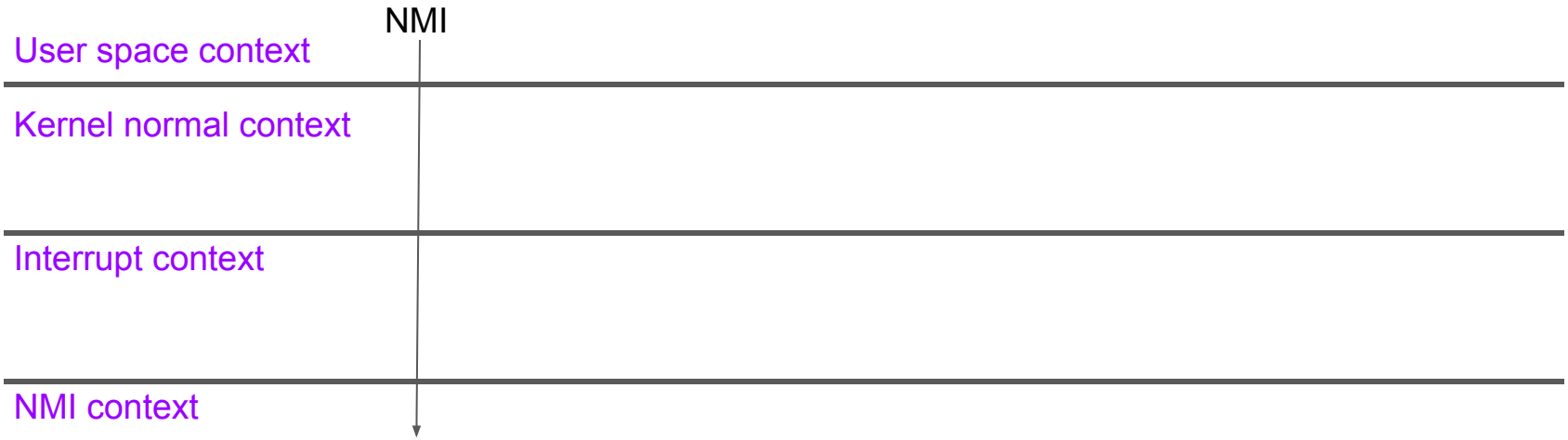
Ptrace path



Perf wants stack trace

(Tries to read the user space stack)

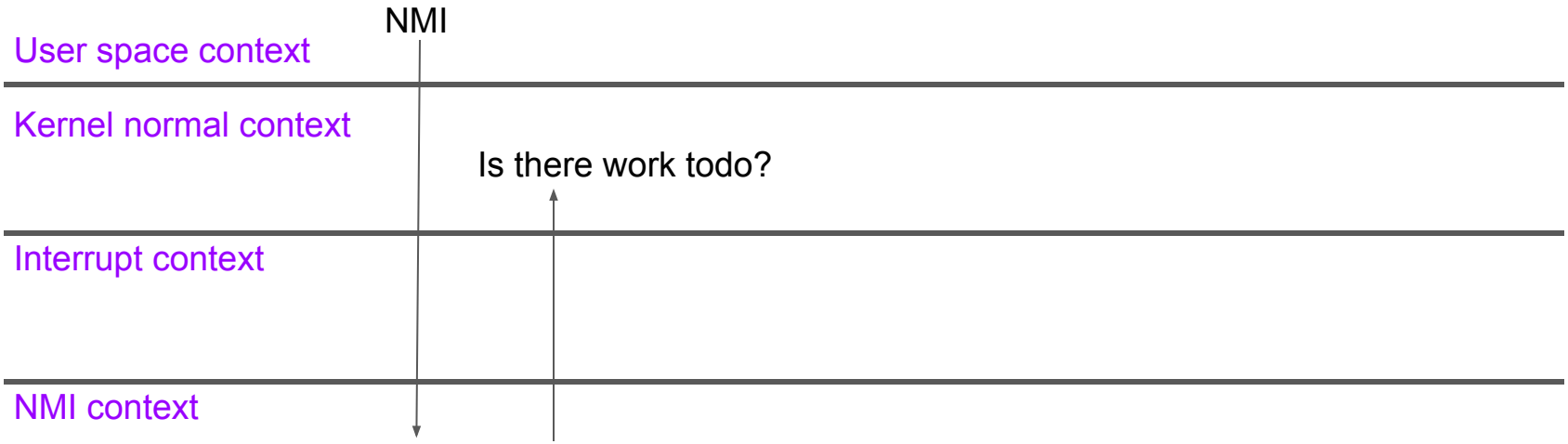
Ptrace path



Perf wants stack trace

Asks sframe infrastructure for stack

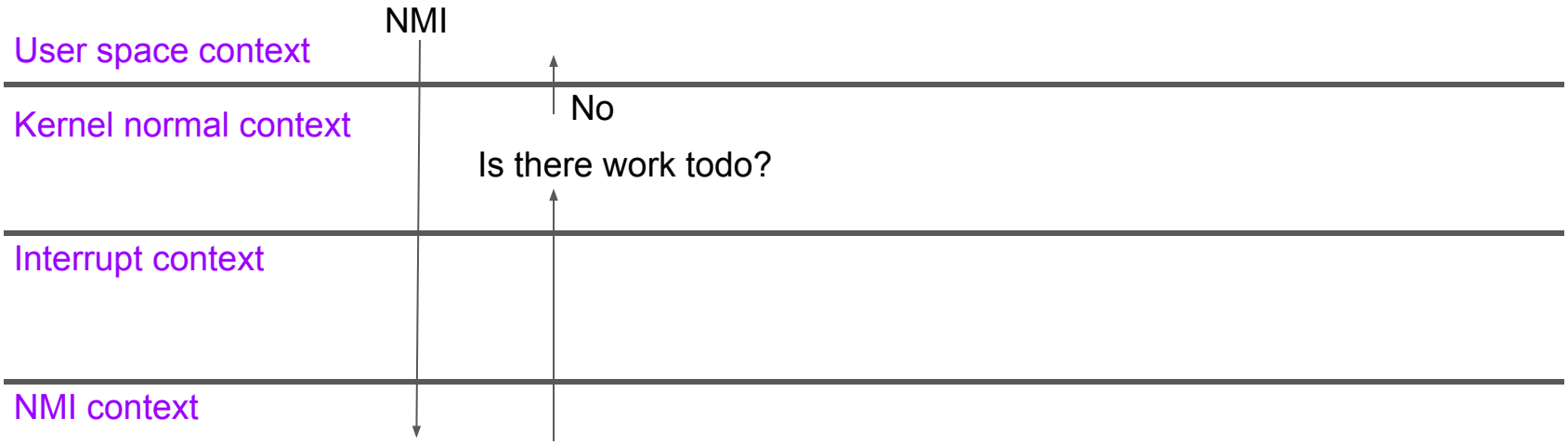
Ptrace path



Perf wants stack trace

Asks sframe infrastructure for stack

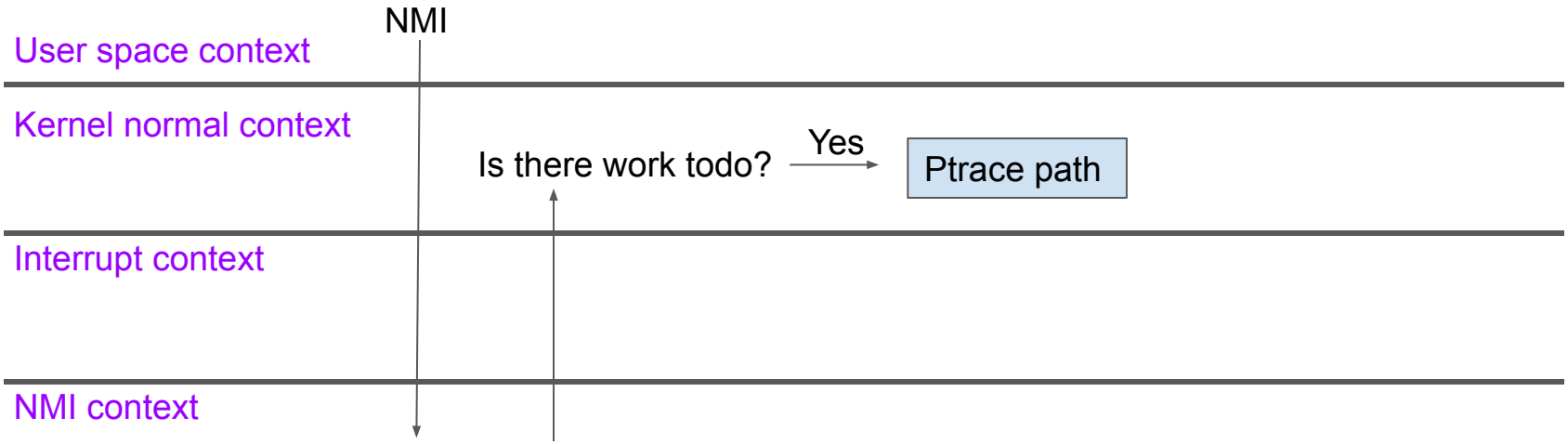
Ptrace path



Perf wants stack trace

Asks sframe infrastructure for stack

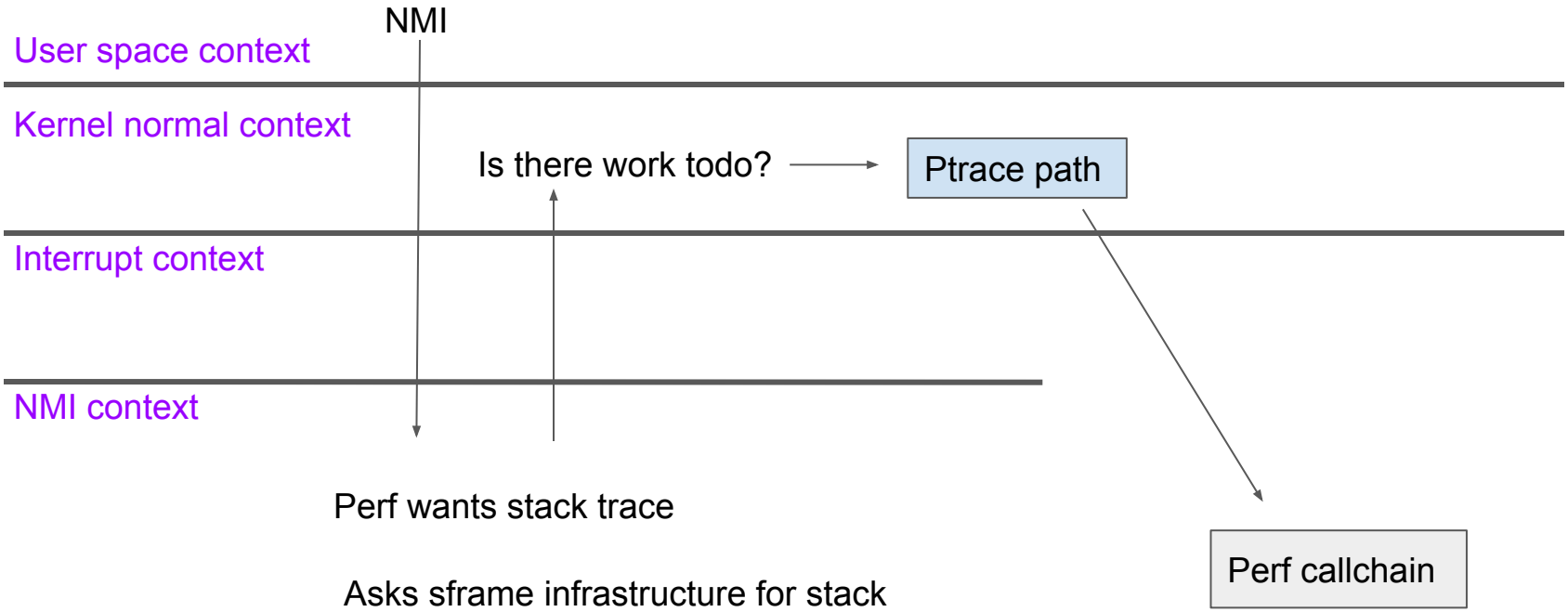
Ptrace path



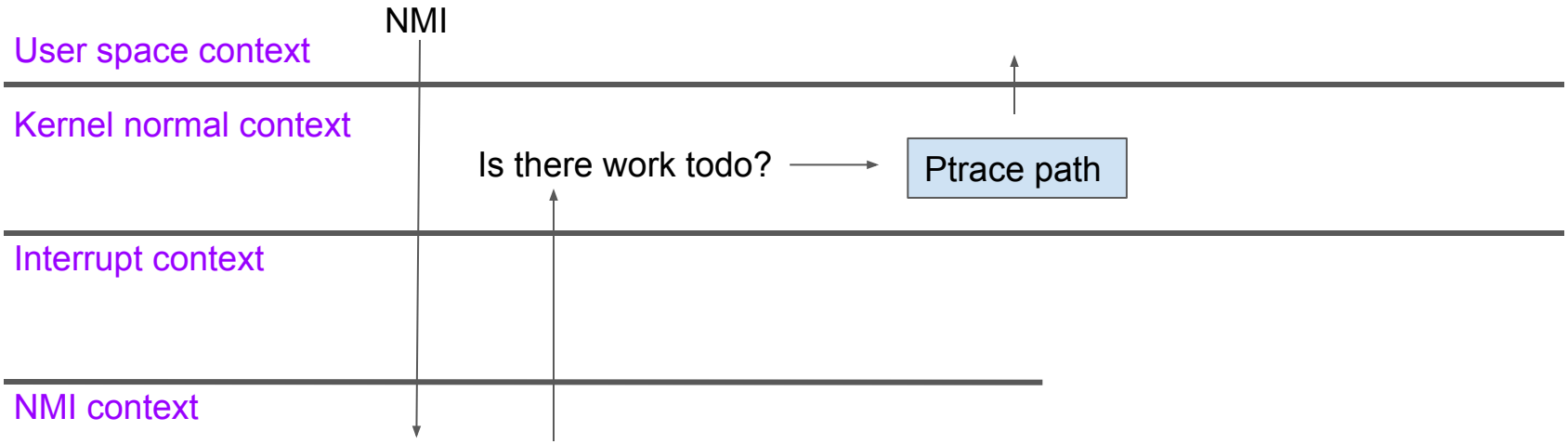
Perf wants stack trace

Asks sframe infrastructure for stack

Ptrace path


NMI
User space context
Kernel normal context
Is there work todo?
Ptrace path
Interrupt context
NMI context
Perf wants stack trace
Asks sframe infrastructure for stack
Perf callchain

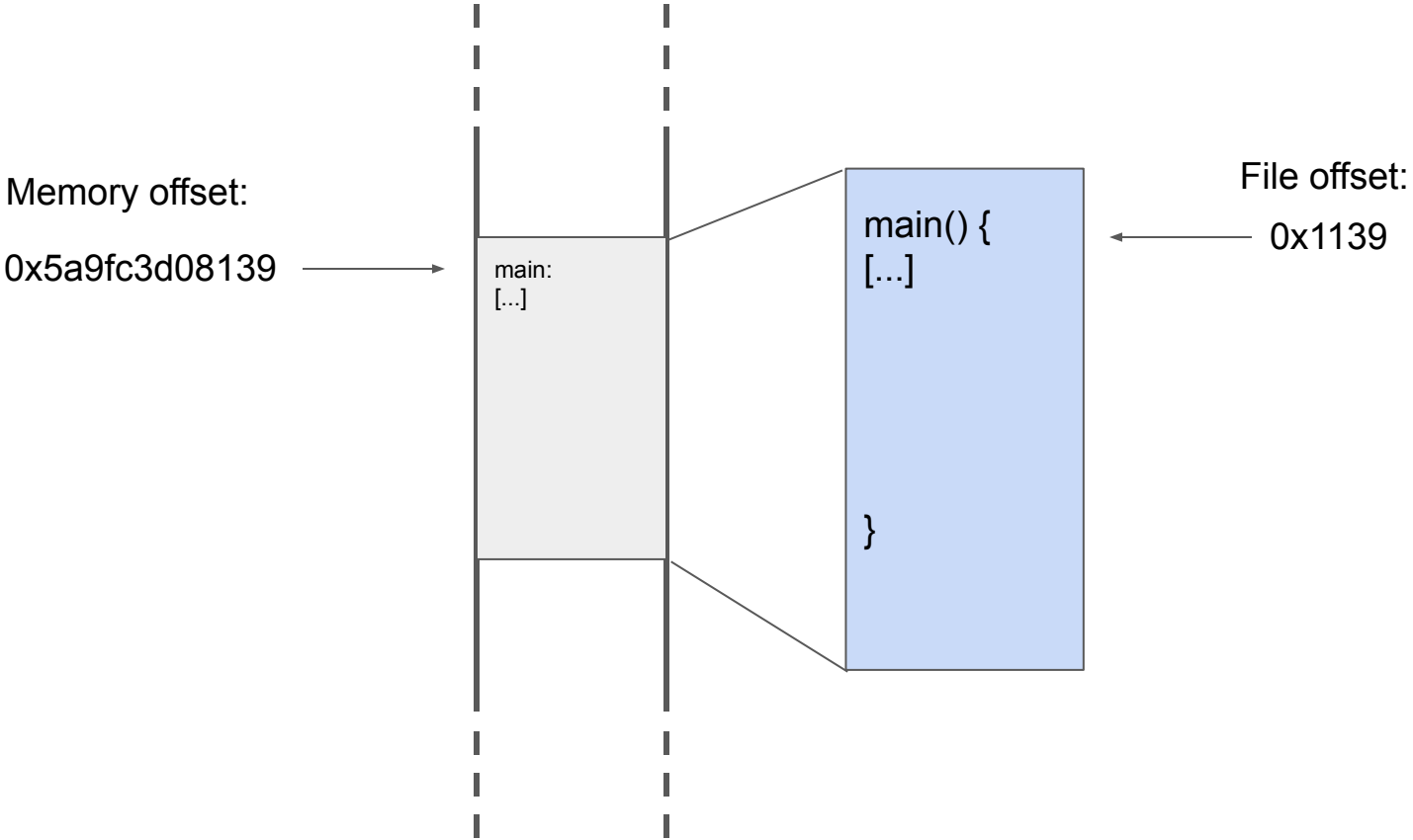
Ptrace path



Perf wants stack trace

Asks sframe infrastructure for stack

Relocational addresses



Use proc mapping

```
# cat /proc/3248/maps
555555554000-555555555000 r--p 00000000 fe:01 2157                       /tmp/t
555555555000-555555556000 r-xp 00001000 fe:01 2157                       /tmp/t
555555556000-555555557000 r--p 00002000 fe:01 2157                       /tmp/t
555555557000-555555558000 r--p 00002000 fe:01 2157                       /tmp/t
555555558000-555555559000 rw-p 00003000 fe:01 2157                       /tmp/t
7ffff7dcf000-7ffff7dd2000 rw-p 00000000 00:00 0
7ffff7dd2000-7ffff7df8000 r--p 00000000 fe:01 263354                     /usr/lib/x86_64-linux-gnu/libc.so.6
7ffff7df8000-7ffff7f4d000 r-xp 00026000 fe:01 263354                     /usr/lib/x86_64-linux-gnu/libc.so.6
7ffff7f4d000-7ffff7fa0000 r--p 0017b000 fe:01 263354                     /usr/lib/x86_64-linux-gnu/libc.so.6
7ffff7fa0000-7ffff7fa4000 r--p 001ce000 fe:01 263354                     /usr/lib/x86_64-linux-gnu/libc.so.6
7ffff7fa4000-7ffff7fa6000 rw-p 001d2000 fe:01 263354                     /usr/lib/x86_64-linux-gnu/libc.so.6
7ffff7fa6000-7ffff7fb3000 rw-p 00000000 00:00 0
7ffff7fc3000-7ffff7fc5000 rw-p 00000000 00:00 0
7ffff7fc5000-7ffff7fc9000 r--p 00000000 00:00 0                          [vvar]
7ffff7fc9000-7ffff7fcb000 r-xp 00000000 00:00 0                          [vdso]
7ffff7fcb000-7ffff7fcc000 r--p 00000000 fe:01 263348                     /usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2
7ffff7fcc000-7ffff7ff1000 r-xp 00001000 fe:01 263348                     /usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2
7ffff7ff1000-7ffff7ffb000 r--p 00026000 fe:01 263348                     /usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2
7ffff7ffb000-7ffff7ffd000 r--p 00030000 fe:01 263348                     /usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2
7ffff7ffd000-7ffff7fff000 rw-p 00032000 fe:01 263348                     /usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2
7ffffffde000-7ffffffff000 rw-p 00000000 00:00 0                          [stack]
ffffffffff600000-ffffffffff601000 --xp 00000000 00:00 0                  [vsyscall]
```

SFrame for JITted code

Stack tracing for JITted code

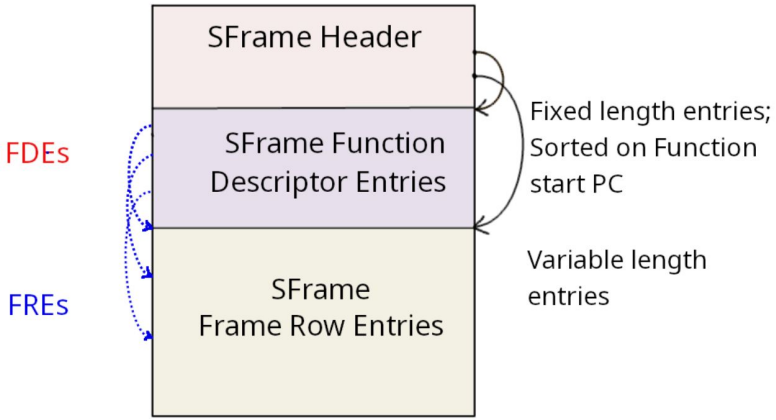
- [WIP] Scoping
  - [#1] How does stack tracing work in JIT environments
  - [#2] Can SFrame make a difference
  - [#3] If yes, Identify the requirements for SFrame to support the JIT usecase
- Current understanding
  - [#1] Interpreted and Compiled application code, and VM’s own code
    - Runtime knows how to walk these variety of stack layouts
  - [#2] Potentially?
  - [#3] Let's talk next...

SFrame for JIT code

- Pre-requisites
  - Stack layout of compiled/interpreted/VM code is psABI compliant.
    - Return address is either on stack (fixed location from CFA) or an ABI identified register
- JIT usecase
  - Functions may be added or removed
  - Functions size and content are modified over time
  - Functions may also be moved to a different location
  - Lifetime of JITted code varies
- Requirements
  - Growable SFrame section:
    - [At function granularity] Allow efficient addition of stacktrace data
    - [At function granularity] Allow efficient removal of stale stacktrace data
    - Support sorted and unsorted FDEs on PC for lookup
  - Lifetime-awareness: Allow efficient management of multiple .sframe sections

Growable SFrame section - I

- Support a “Growable” model
  - Create: Leave space in SFrame FDEs subsection, and SFrame FRE subsection
  - Append: If space available, add FDEs and the associated FREs; Else, create a new “Growable” SFrame section and copy over.
  - Delete: Mark as invalid. Provide means for deferred compaction.
- SFrame header flag SFRAME_F_FDE_SORTED

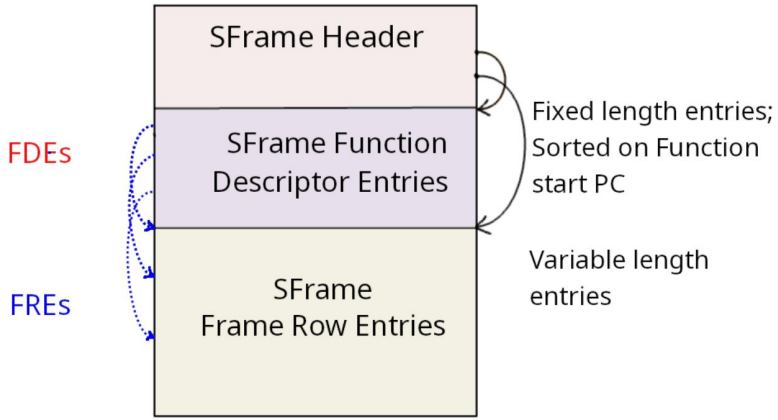


Growable SFrame section - II

- SFrame FDE: Add 1 bit to mark valid/invalid SFrame FDEs
  - Defer “Compaction” until when it's a good time
- SFrame Header: Add new 32-bit offset to identify total size of SFrame FRE sub-section

Existing:

```
uint32_t sfh_fre_len;
/* Offset of SFrame Function Descriptor Entry section.  */
```



- Add Compaction APIs for JIT Runtime

Lifetime-awareness using SFrame

- Lifetime of some jitted code is short
  - Address space gets reused
- Support multiple .sframe sections per process
  - Creation, management and bookkeeping may be left to the runtime
  - Is format level specification/support necessary?