klp-convert and livepatch relocations

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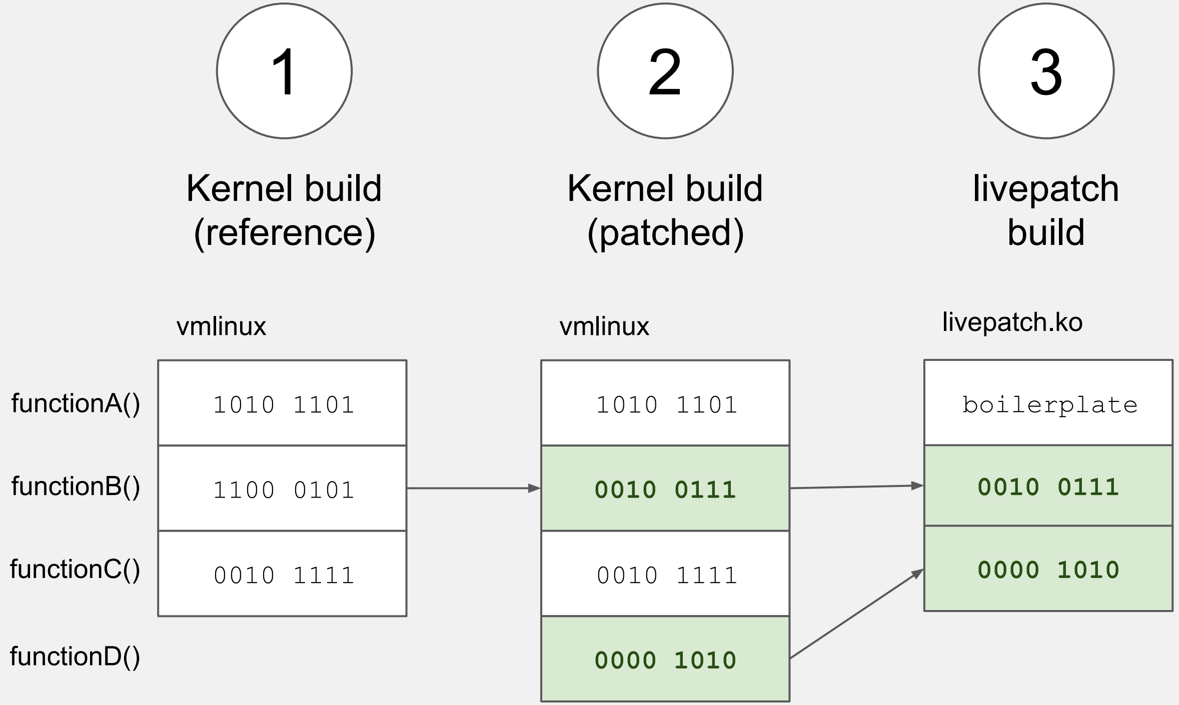
klp-convert patchset history

(Josh Poimboeuf) RFC:
https://lore.kernel.org/lkml/cover.1477578530.git.jpoimboe@redhat.com/

(João Moreira) v2:
https://lore.kernel.org/lkml/f52d29f7-7d1b-ad3d-050b-a9fa8878faf2@redhat.com/

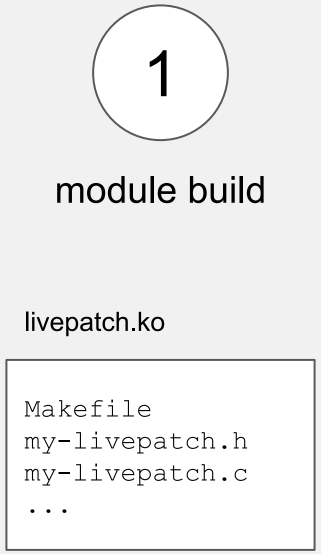
(Joe Lawrence) v3:
https://lore.kernel.org/lkml/20190410155058.9437-1-joe.lawrence@redhat.com/
v4:
https://lore.kernel.org/lkml/20190509143859.9050-1-joe.lawrence@redhat.com/
v5:
(kbuild cleanup from Masahiro Yamada, review comments from Miroslav Beneš, misc bugfixes)

Creating livepatches: kpatch-build



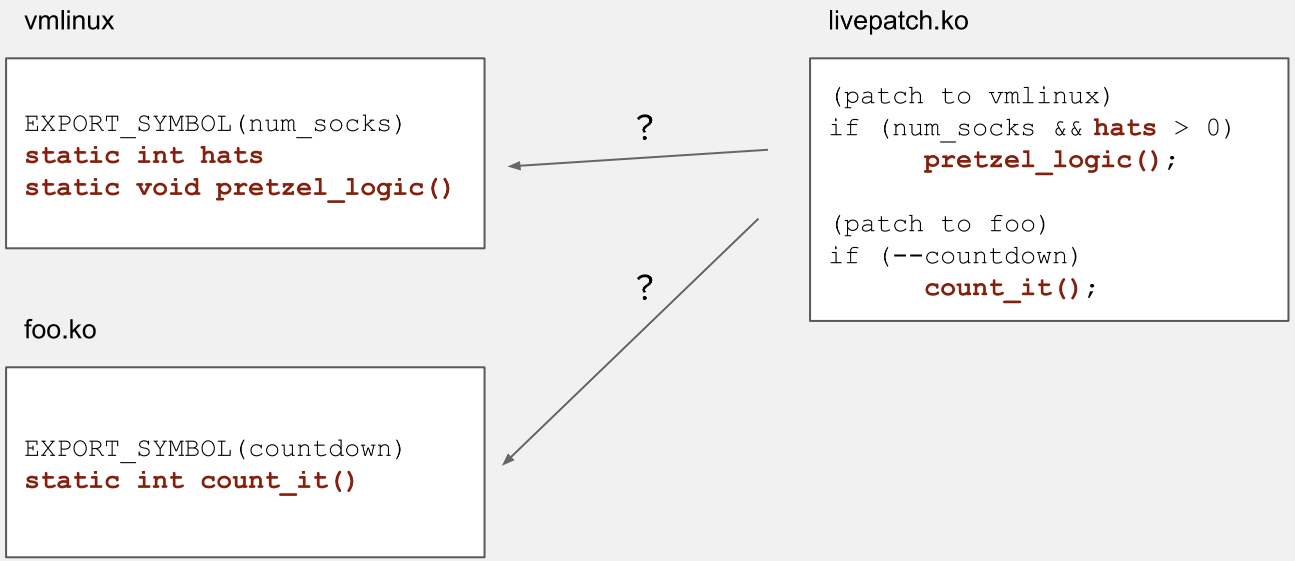
VS...

Creating livepatches: source-based



Just an “ordinary” kernel module build, no external tooling, real sources.

Problem: unexported symbols



vmlinux

```
EXPORT_SYMBOL(num_socks)
static int hats
static void pretzel_logic()
```

foo.ko

```
EXPORT_SYMBOL(countdown)
static int count_it()
```

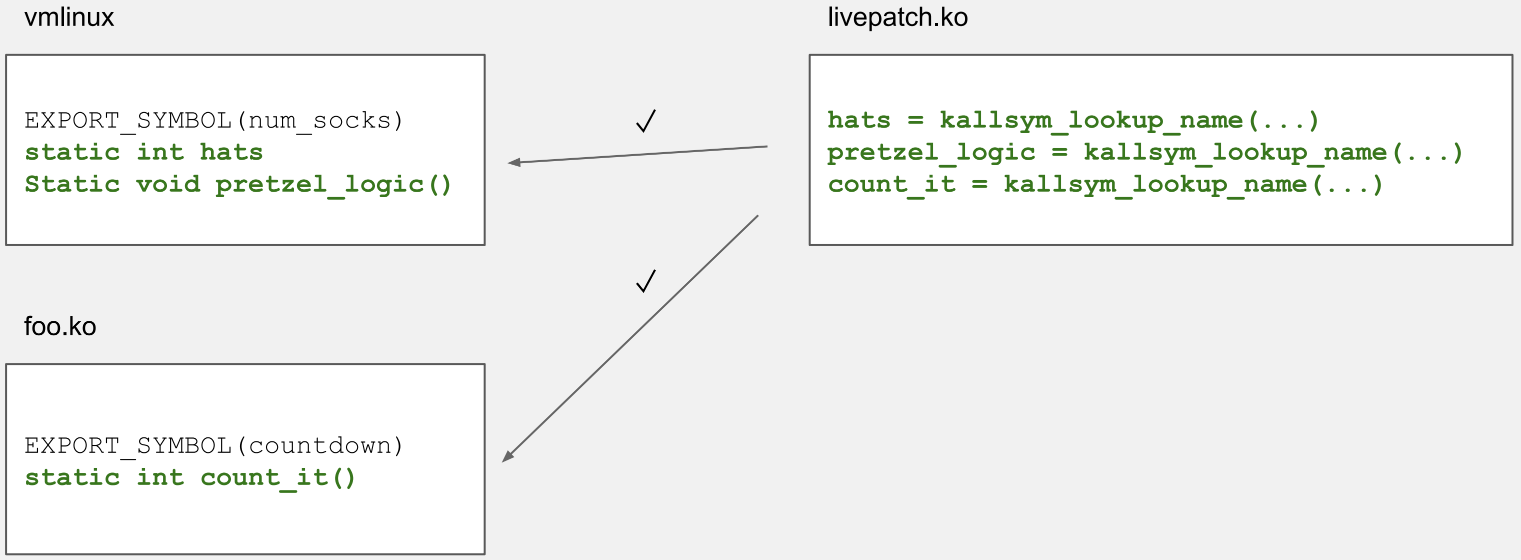
livepatch.ko

```
(patch to vmlinux)
if (num_socks && hats > 0)
      pretzel_logic();

(patch to foo)
if (--countdown)
      count_it();
```

How to access unexported symbols from livepatches?

Workaround 1: unexported symbols



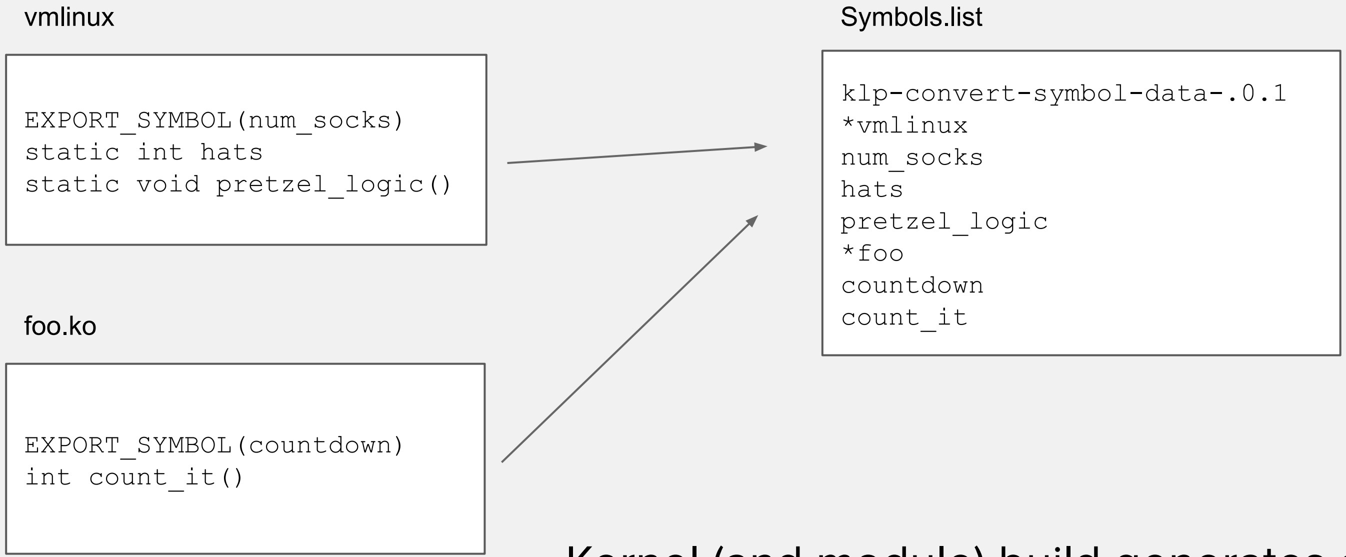
```
EXPORT_SYMBOL(num_socks)
static int hats
Static void pretzel_logic()
```

```
hats = kallsym_lookup_name(...)
pretzel_logic = kallsym_lookup_name(...)
count_it = kallsym_lookup_name(...)
```

```
EXPORT_SYMBOL(countdown)
static int count_it()
```

Use kallsyms to manually lookup symbol names, access via pointer indirection, or ...

Workaround 2: klp-convert, part a



vmlinux

```
EXPORT_SYMBOL(num_socks)
static int hats
static void pretzel_logic()
```

foo.ko

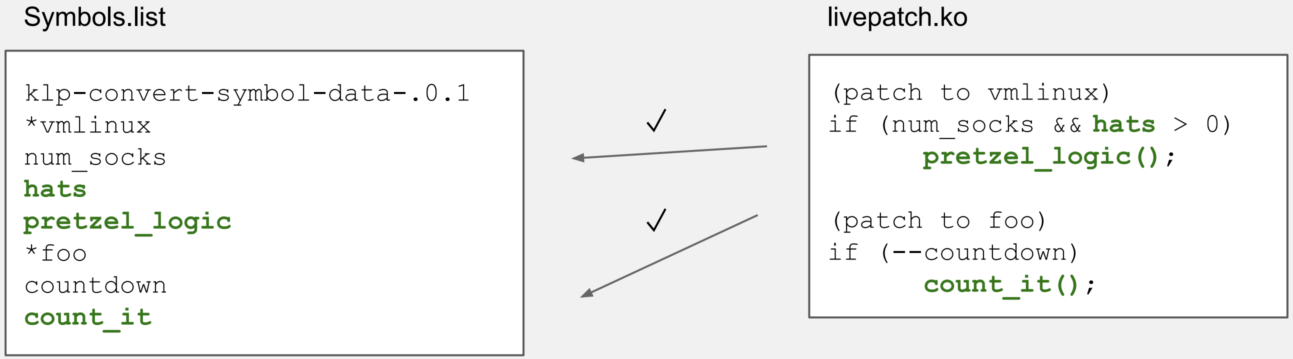
```
EXPORT_SYMBOL(countdown)
int count_it()
```

Symbols.list

```
klp-convert-symbol-data-.0.1
*vmlinux
num_socks
hats
pretzel_logic
*foo
countdown
count_it
```

Kernel (and module) build generates a database of objects and their symbols...

Workaround 2: klp-convert, part b



Symbols.list

```
klp-convert-symbol-data-.0.1
*vmlinux
num_socks
hats
pretzel_logic
*foo
countdown
count_it
```

livepatch.ko

```
(patch to vmlinux)
if (num_socks && hats > 0)
      pretzel_logic();

(patch to foo)
if (--countdown)
      count_it();
```

Symbols.list + livepatch.tmp.ko = livepatch.ko

With the symbol database, klp-convert can resolve unique symbols.

klp-convert: relocation magic

```
Relocation section '.klp.rela.vmlinux..text' at offset 0x4c278 contains 2 entries:
      Type                       Symbol's Name + Addend
      R_X86_64_32S         .klp.sym.vmlinux.hats,0 + 0
      R_X86_64_PC32              .klp.sym.vmlinux.pretzel_logic,0 - 4

Relocation section '.klp.rela.foo..text' at offset 0x4c278 contains 1 entry:
      Type                       Symbol's Name + Addend
      R_X86_64_PC32              .klp.sym.foo.count_it,0 - 4
```

Section name format:
  .klp.rela.objname.section_name

Symbol name format:
  .klp.sym.objname.symbol_name,sympos

Unresolved symbols are encoded as “livepatch” relocations, placed in specially named sections as specially named symbols.

Livepatch relocations: kernel support

- Documentation/livepatch/module-elf-format.rst

- kernel/livepatch/core.c
  - klp_resolve_symbols()
  - klp_write_object_relocations()

- **arch/x86/kernel/livepatch.c**
  - **arch_klp_init_object_loaded()**
  - **No klp-convert support**

Arch-specific section name format:
.klp.arch.objname.section_name

Kernel support for architecture-specific livepatch relocations have been added for x86 (only) `.altinstructions` and `.parainstructions`

Special section example: .smp_locks

```
__used static notrace void foo(void)
{
      asm volatile(LOCK_PREFIX "nop");
}

Disassembly of section .text:

0000000000000000 <foo>:
   0:   f0 90                   lock nop        <-------------
   2:   c3                      retq                         |
   ...                                                       |
                                                             |
Disassembly of section .smp_locks:                           |
                                                             |
0000000000000000 <.smp_locks>:                               |
   0:   00 00                   add   %al,(%rax)             |
                       0: R_X86_64_PC32        .text   ----
```

Boring example, relocation is local to the module, so no klp-convert implications.

Special section example: .altinstructions

```
alternative("call foo1", "call foo2", X86_FEATURE_FPU)

      .altinstructions                      .rela.altinstructions
 ----    old = (reloc) patch spot             a
|  --    new = (reloc) alt instr spot         b
| |      feature
| |      old_len, new_len, pad_len
| |
| |   .text                                 .rela.text
 -|-->   call (reloc) foo1                    c
  |      < nop pads >
  |
  |   .altinst_replacement                  .rela.altinst_replacement
   -->   call (reloc) foo2                    d
```

`.rela.altinstructions` is module-local, but `.rela.text` and `.rela.altinst_replacement` possibly not.

Special section example: .altinstructions

```
load_module

  apply_relocations

  post_relocation
    module_finalize
      apply_alternatives                         << pick new or old to patch in

      ...

  do_init_module
    do_one_initcall(mod->init)
      __init patch_init [kpatch-patch]
        klp_register_patch
          klp_init_patch
            klp_for_each_object(patch, obj)
              klp_init_object
                klp_init_object_loaded
                  klp_write_object_relocations      << resolve livepatch relocs
```

Special section example: .altinstructions

Ordering problem:

1. Load patch module
2. Apply alternatives to livepatch module
3. Apply per-object relocations to livepatch module when target module loads, clobbering (2)

Correct order:

1. Load patch module
2. Apply per-object relocations to livepatch module
3. Apply alternatives and paravirt patches to patch module

Delay alternatives patching until after livepatch relocations are applied.

Special section example: .altinstructions

Kpatch-build already handles this and moves sections:

```
.altinstructions          ->          .klp.arch.<obj>..altinstructions
.rela.altinstructions     ->          .rela.klp.arch.<obj>..altinstructions
```

The `.altinst_replacement` section remains intact, but kpatch-build does move its converted relocations `.klp.rela.<obj>..altinst_replacement` as per usual livepatch symbol/relocation conversion.

klp-convert:

TODO

Special section example: __jump_table

```
extern struct static_key_false module_key;
__used static notrace void foo(void)
{
	if (static_branch_likely(&module_key))
		asm("nop 1");
	else
		asm("nop 2");

	asm("nop 3");
}
```

Special section example: __jump_table

```
       Disassembly of section .text:

       0000000000000000 <foo>:
  ->      0:   e9 11 00 00 00          jmpq   16 <foo+0x16>
   |      5:   0f 1f 04 25 01 00 00    nopl   0x1
   |      c:   00
   |      d:   0f 1f 04 25 03 00 00    nopl   0x3
   |     14:   00
   |     15:   c3                      retq
 ---->   16:   0f 1f 04 25 02 00 00    nopl   0x2
| |      1d:   00
| |      1e:   eb ed                   jmp d <foo+0xd>
| |
| |
| |  Relocation section [ 8] '.rela__jump_table' for section [ 7] '__jump_table'
| |   Offset            Type        Value             Addend    Name
|  --   000000000000000000  X86_64_PC32    000000000000000000      +0   .text
 ----   0x0000000000000004  X86_64_PC32    000000000000000000      +22  .text
        0x0000000000000008  X86_64_PC64    000000000000000000      +0   module_key
```

Static key `code` and `target` are module-local relocations

But the `key` may be external.

Special section example: __jump_table

- kpatch-build, klp-convert: TODO

- Once again, we will need to do some relocation / section book-keeping:
  - For any jumpy label key-value relocation that requires livepatch relocation type
    - Move it into an arch-specific section

  - Update arch_klp_init_object_loaded() to initialize this particular static key

- TBD: is this enough? Does the jump label code make assumptions about __jump_table and whether all structures can be considered “live”
  - e.g. need to resize and dynamically manage struct module’s jump_entries array?

More TODO

- How many other arch-specific sections do we need to worry about?
  - We will need good regression tests to aid long-term stability.
- External modules: should we support out-of-tree livepatch builds that require klp-convert?
  - Can out-of-tree modules provide their own Symbols.list?
- BFD library bug: bz-24456
  - Doesn't like multiple relocation sections to same (.text) section
  - Affects objdump, gdb, crash utility
  - Mitigation recently checked into binutils
    - a7ba389645d1 ("Stop the BFD library from failing when encountering a second set of relocs for the same section.")

THANK YOU