Support for mini-debuginfo in LLDB

How to read the .gnu_debugdata section

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About me

Konrad Kleine

- Red Hat
- LLDB, C/C++, ELF, DWARF since 2019
- Before worked OpenShift since 2016

Reach out

- https://github.com/kwk/talks/
- https://www.linkedin.com/in/konradkleine
- https://developers.redhat.com/blog/author/kkleine/

⌖ Overall goal

Improve LLDB for Fedora and RHEL binaries

- when no debug symbols installed
    - backtraces only show addresses
    - runtime symbols stored in special location

Approach

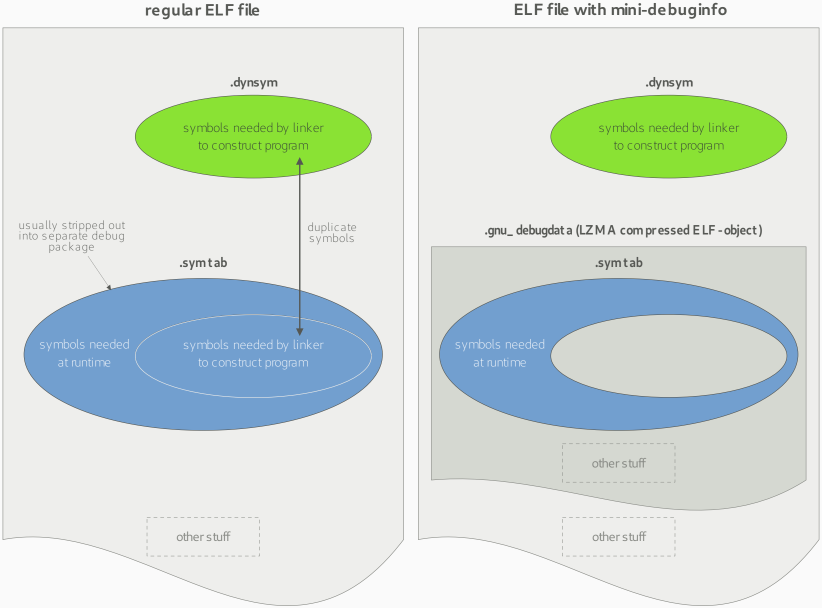
- make LLDB understand mini-debuginfo
    - that's where runtime symbols are stored

Why was mini-debuginfo invented?

- without installing debug infos
  - be able to generate a backtrace for crashes with ABRT[1]
  - have symbol table (`.symtab`)
  - have line information (`.debug_line`)
  - ➔ *more than two sections make an ELF file* ☺
- eventually only one relevant section
  - stripped `.symtab`
  - rest was too big
  - format remained
  - **no replacement** for separate full debug info
  - **not related** to DWARF
    - *just symbol tables*

[1] Automatic Bug Reporting Tool

Symbol tables in an ELF file



regular ELF file
ELF file with mini-debuginfo
.dynsym
symbols needed by linker to construct program
usually stripped out into separate debug package
duplicate symbols
.symtab
symbols needed at runtime
symbols needed by linker to construct program
other stuff
.dynsym
symbols needed by linker to construct program
.gnu_debugdata (LZMA compressed ELF-object)
.symtab
symbols needed at runtime
other stuff
other stuff

Where and since when is mini-debuginfo being used?

- RPM since 4.13.0-rc2 (2016)
- On by default since Fedora 18 (2013, Release Notes 4.2.4.1.)
- Red Hat Enterprise Linux (RHEL) since 7

Approach

Not focus on backtraces

- but make LLDB see mini-debuginfo
  - symbol awareness through
    - set and hit breakpoint
    - dump symbols (`(lldb) image dump symtab`)

Take existing Fedora binary (`/usr/bin/zip`)

- identify a symbol/function
- shootout: GDB vs. LLDB
- hurdles:
  - not from `.dynsym`
  - from within `.gnu_debugdata`

Extract and uncompress `.gnu_debugdata` section to `zip.gdd`

```
~$ cp /usr/bin/zip .
~$ objcopy --dump-section .gnu_debugdata=zip.gdd.xz zip
~$ file zip.gdd.xz
zip.gdd.xz: XZ compressed data
~$ xz --decompress --keep zip.gdd.xz
~$ file zip.gdd
zip.gdd: ELF 64-bit LSB executable, x86-64, version 1 [...]
```

Identify symbol in `zip.gdd` but not in main binary

```
~$ eu-readelf -s zip.gdd

Symbol table [28] '.symtab' contains 202 entries:
 82 local symbols  String table: [29] '.strtab'
  Num:            Value   Size Type    Bind   Vis          Ndx Name
    0: 0000000000000000      0 NOTYPE  LOCAL  DEFAULT    UNDEF
    1: 0000000000408db0    494 FUNC    LOCAL  DEFAULT       15 freeup
    2: 0000000000408fa0   1015 FUNC    LOCAL  DEFAULT       15 DisplayRunningStats
    3: 00000000004093a0    128 FUNC    LOCAL  DEFAULT       15 help
[...]
```

`help` looks promising[2].

```
~$ eu-readelf --symbols /usr/bin/zip | grep help
~$
```

[2]Promising as in: we may be able to trigger it with `/usr/bin/zip --help`.

Set and hit breakpoint on `help` with GDB 8.3[3]

```
~$ gdb --nx --args /usr/bin/zip --help
Reading symbols from /usr/bin/zip...
Reading symbols from .gnu_debugdata for /usr/bin/zip...
(No debugging symbols found in .gnu_debugdata for /usr/bin/zip)
Missing separate debuginfos, use: dnf debuginfo-install zip-3.0-25.fc31.x86_64
(gdb) b help
Breakpoint 1 at 0x4093a0
(gdb) r
Starting program: /usr/bin/zip --help

Breakpoint 1, 0x00000000004093a0 in help ()
(gdb)
```

Success and two things to note:

1. Symbols read from `.gnu_debugdata`
2. No debug symbols installed for zip

[3] GDB 8.3 is what ships with Fedora 31

Set and hit breakpoint on `help` with LLDB 9.0.0[4]

```
~$ lldb -x /usr/bin/zip -- --help
(lldb) target create "/usr/bin/zip"
Current executable set to '/usr/bin/zip' (x86_64).
(lldb) settings set -- target.run-args  "--help"
(lldb) b help
Breakpoint 1: no locations (pending).
WARNING:  Unable to resolve breakpoint to any actual locations.
(lldb)
```

☹ 👉

[4] LLDB 9.0.0 is what ships with Fedora 31

⚠ Let's talk `.symtab`

Symtab

- normally, `.dynsym` is subset
- **but** for mini-debuginfo `.dynsym` symbols are stripped[5]

Implications for LLDB (and other tools)

- parse `.dynsym` when
  - no `.symtab` found **or**
  - mini-debuginfo present and smuggled in

[5] https://sourceware.org/gdb/current/onlinedocs/gdb/MiniDebugInfo.html

☑ Show that LLDB can now find `help` symbol

```
$ lldb -x /usr/bin/zip -- --help
(lldb) target create "/usr/bin/zip"
Current executable set to '/usr/bin/zip' (x86_64).
(lldb) settings set -- target.run-args  "--help"
(lldb) b help
Breakpoint 1: where = zip`help, address = 0x00000000004093a0
(lldb) r
Process 277525 launched: '/usr/bin/zip' (x86_64)
Process 277525 stopped
* thread #1, name = 'zip', stop reason = breakpoint 1.1
    frame #0: 0x00000000004093a0 zip`help
zip`help:
->  0x4093a0 <+0>:  pushq  %r12
    0x4093a2 <+2>:  movq   0x2af6f(%rip), %rsi       ;  + 4056
    0x4093a9 <+9>:  movl   $0x1, %edi
    0x4093ae <+14>: xorl   %eax, %eax
(lldb)
```

♡ shipping with LLVM 10

🚢 Ready to ship?

? What tests exists for mini-debuginfo?

- find symbol from `.gnu_debugdata`
- warning when decompressing `.gnu_debugdata` w/o LZMA support
- error when decompressing corrupted xz
- full example with compiled and modified code in accordance to gdb's documentation

🛏 fell asleep yet?

</> Example test file in Shell test suite

lldb/test/Shell/Breakpoint/example.c:

```c
// REQUIRES: system-linux, lzma, xz
// RUN: gcc -g -o %t %s
// RUN: %t 1 2 3 4 | FileCheck %s

#include <stdio.h>
int main(int argc, char* argv[]) {

  // CHECK: Number of {{.*}}: 5
  printf("Number of arguments: %d\n", argc);

  return 0;
}
```

```
~/llvm-project$ llvm-lit lldb/test/Shell/Breakpoint/example.c
-- Testing: 1 tests, 1 workers --
PASS: lldb-shell :: Breakpoint/example.c (1 of 1)

Testing Time: 0.20s
  Expected Passes    : 1
```

You might wonder. . .

- what was the hardest part?
  - polishing for upstream
  - dealing with tests
    - non-runnable/sparse ELF files produced from some YAML
- set **and** hit a breakpoint
  - only possible with runnable ELF file

Thank you!

Please, share your feedback ★★★★★

https://submission.fosdem.org/feedback/10393