Fosdem 2015

perf status on ARM and ARM64

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Introduction

- Scope of the presentation
  - Work done for Linaro LEG:
    - profiling tools for servers load,
    - features parity with x86.
  - This presentation is about the call stack unwinding on ARM/ARM64, using fp and dwarf methods.
- Tool in use: perf

Call stack unwinding

- General
  - perf tool regularly captures (perf record) the current state and then parses the data (perf report).
  - perf links with unwinding libraries.
  - Unwinding allows to trace the callers up to the current execution point.

  - Example: The 'stress_bt' application consists of a long call chain (foo_1 calling foo_2 calling ... foo_128). foo_128 performs some calculation on u64 variables. The main loop calls foo_1, foo_2 ... foo_128 in order.
  - Without and with unwinding:

Call stack unwinding

- Without and with unwinding:

```
# perf record

 usage: perf record [<options>] [<command>]
    or: perf record [<options>] -- <command> [<options>]
...
    -g                    enables call-graph recording
        --call-graph <mode[,dump_size]>
                          setup and enables call-graph (stack chain/backtrace)
recording: fp dwarf


# perf record -- ./stress_bt
# perf report
    98.34%  stress_bt  stress_bt              [.] foo_128
     0.11%  stress_bt  stress_bt              [.] foo_127
     0.10%  stress_bt  libc-2.17-2013.07-2.so  [.] random
     0.08%  stress_bt  stress_bt              [.] foo_93
     0.07%  stress_bt  stress_bt              [.] foo_89
…
     0.01%  stress_bt  [kernel.kallsyms]   [k] unmap_single_vma
     0.01%  stress_bt  [kernel.kallsyms]   [k] unmapped_area_topdown

     0.01%  stress_bt  stress_bt              [.] foo_94
     0.01%  stress_bt  stress_bt              [.] foo_28
     0.01%  stress_bt  stress_bt              [.] foo_49
     0.01%  stress_bt  stress_bt              [.] foo_62
     0.01%  stress_bt  stress_bt              [.] foo_65
     0.01%  stress_bt  [kernel.kallsyms]   [k] __do_fault
...
```

```
#perf record --call-graph dwarf -- ./stress_bt
#perf report (--call-graph --stdio)
    96.93%  stress_bt  stress_bt              [.] foo_128

            |
            --- foo_128
               |
               |--98.22%-- foo_127
               |          |
               |          |--99.46%-- foo_126
               |          |          |
               |          |          |--99.11%-- foo_125
...
               |          |          |
               |          |           --0.89%-- bar
               |          |                     doit
               |          |                     main
               |          |                     __libc_start_main
               |          |
...
               |--0.77%-- bar
               |          doit
               |          main
               |          __libc_start_main
                --1.01%-- [...]

     0.25%  stress_bt  [kernel.kallsyms]       [k] page_mkclean

            |
            --- page_mkclean
```

Call stack unwinding

- General
  - There are different methods to allow the use of call stack unwinding.
  - Support is needed from:
    - Compiler + compilation options,
    - kernel arch code,
    - perf tool + external libraries (libunwind, libdw).

- Methods
  - .exidx
  - frame pointer
  - dwarf

Call stack unwinding

- Method: .exidx
  - Unwinding info stored in specific ELF sections *.ARM.exidx* and *.ARM.extab*.
  - Generated by GCC under *-funwind-tables* and *-fasynchronous-unwind-tables*.
  - No change -so no overhead- to the code.
  - Overhead to the binary size.
  - Supported by libunwind on ARM.
  - Not supported by perf.

Call stack unwinding

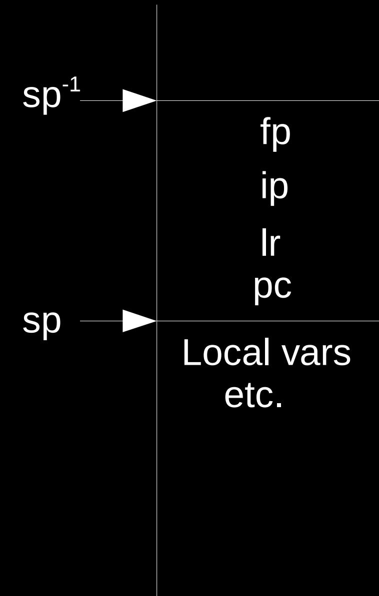
- Method: frame pointer
  - Defined by the ABI
  - During execution the context is stored on the stack as a linked list of stack frames. fp is the frame pointer.

    fp = old sp, similar to *lr = old pc*.
  - Generated by GCC under *-fno-omit-frame-pointer*. Not enabled by default.
  - Code overhead for the stack handling, code size overhead.

Call stack unwinding

- Method: frame pointer

```
; Prologue - setup
mov    ip, sp                ; get a copy of sp.
stm    sp!, {fp, ip, lr, pc}  ; Save the frame on the stack.
sub    fp, ip, #4            ; Set the new frame pointer.
   ...
; Function code comes here
; Could call other functions from here
   ...
; Epilogue - return
ldm    sp, {fp, sp, lr}      ; restore stack, frame pointer and old link.
bx     lr                    ; return.
```



Call stack unwinding

- Method: dwarf
  - Unwinding info stored in specific ELF section *.debug_frame*.
  - Platform independent format.
  - Generated by GCC under *-g*.
  - Overhead only to the debug binary size.
  - On most distros the *-dbg* flavor of the libraries in */usr/lib/debug/lib* usually contain the correct debug information.
  - No change -so no overhead- to the code.

Call stack unwinding

- Method: dwarf

```
# dwarfdump -f -kf stress_bt
.debug_frame

fde:
<    0><0x0000842c:0x00008498><foo_128><fde offset 0x00000010 length: 0x00000014><eh offset none>
        0x0000842c: <off cfa=00(r13) >
        0x0000842e: <off cfa=04(r13) > <off r14=-4(cfa) >
        0x00008430: <off cfa=24(r13) > <off r14=-4(cfa) >
<    0><0x00008498:0x000084a4><foo_127><fde offset 0x00000028 length: 0x00000014><eh offset none>
        0x00008498: <off cfa=00(r13) >
        0x0000849a: <off cfa=08(r13) > <off r3=-8(cfa) > <off r14=-4(cfa) >
...
<    0><0x00008ccc:0x00008cf2><main><fde offset 0x00000c40 length: 0x00000014><eh offset none>
        0x00008ccc: <off cfa=00(r13) >
        0x00008cce: <off cfa=04(r13) > <off r14=-4(cfa) >
        0x00008cd0: <off cfa=16(r13) > <off r14=-4(cfa) >
```

```
cie:
<    0> version                        1
        cie section offset             0 0x00000000
        augmentation
        code_alignment_factor          2
        data_alignment_factor         -4
        return_address_register       14
        bytes of initial instructions  3
        cie length                    12
        initial instructions
         0 DW_CFA_def_cfa r13 0
```

Call stack unwinding

- Gotchas (= Corner Cases)
  - 32-bit compatibility mode
    - A 32-bit ARM binary can run on ARM64.
    - The unwinding on ARM64 has to correctly handle the 32-bit structs (registers, fp struct, dwarf info...).
    - The impact is on all components (kernel, perf, libraries etc.).

Call stack unwinding

- Gotchas (= Corner Cases)
  - tail call optimization
    - No code for the stack frame handling for a tail call.
    - Confuses the fp based unwinding.
    - Dwarf info encodes the call chain.
    - Need more check/test.

```
void bar(int val)
{
        printf("Meet @ bar\n");
        return;
}

void foo(int val)
{
        bar(x);
        return;
}

int main()
{
        foo(42);
        return 0;
}
```

Call stack unwinding

- Gotchas (=Corner Cases)
  - ARM assembly directives
    - Example: generic register used as link register.
    - It seems that dwarf correctly encodes the info but unwinding is not OK.
    - Need more check/test

arch/arm64/kernel/vdso/gettimeofday.S:

```
ENTRY(__kernel_gettimeofday)
	.cfi_startproc
	mov	x2, x30
	.cfi_register x30, x2

	/* Acquire the sequence counter and get the timespec. */

	adr	vdso_data, _vdso_data
1:	seqcnt_acquire
	cbnz	use_syscall, 4f
…
	ret	x2
	.cfi_endproc

ENDPROC(__kernel_gettimeofday)
```

ARM and ARM64 support

- Kernel arch code
- perf code + test suite
- External libraries

	arch: fp	arch: dwarf	perf: libunwind	perf: libdw	Perf: test suite	Compat mode
ARM	v	v	v	v	v	v
ARM64	v	v	v	x submitted	x submitted	v

Next steps, follow-up

- Submitted patches, to check
  - Generic: tracing with kernel tracepoints events
    https://lkml.org/lkml/2014/7/7/282
  - ARM64 libdw

    https://lkml.org/lkml/2014/5/6/395
  - ARM64 test suite

    https://lkml.org/lkml/2014/5/6/392

    https://lkml.org/lkml/2014/5/6/398
- Tail call optimization: to check
- ARM directives: to check
- .exidx support in perf?

References

- ARM Exception Handling ABI: http://infocenter.arm.com/help/topic/com.arm.doc.ihi0038a/IHI0038A_ehabi.pdf
- Unwinding on ARM: https://wiki.linaro.org/KenWerner/Sandbox/libunwind?action=AttachFile&do=get&target=libunwind-LDS.pdf
- Details on libunwind and .exidx unwinding: https://wiki.linaro.org/KenWerner/Sandbox/libunwind
- Dwarf unwinding details: https://wiki.linaro.org/LEG/Engineering/TOOLS/perf-callstack-unwinding
- libunwind: http://www.nongnu.org/libunwind/
- libdw/elfutils: https://fedorahosted.org/elfutils/
- ARM directives: http://sourceware.org/binutils/docs/as/ARM-Directives.html
- LKML and linux-arm-kernel MLs
- perf IRC channel: #perf at irc.oftc.net

Questions?

Thank you!

Back-up slides

- perf compilation. ! Use a recent libunwind dev library !

```
$ make LIBUNWIND_DIR=/usr/local NO_LIBDW_DWARF_UNWIND=1 -C tools/perf
...
Auto-detecting system features:
...                         dwarf: [ on  ]
...                         glibc: [ on  ]
...                          gtk2: [ OFF ]
...                      libaudit: [ on  ]
...                        libbfd: [ on  ]
...                        libelf: [ on  ]
...                       libnuma: [ OFF ]
...                       libperl: [ on  ]
...                     libpython: [ on  ]
...                      libslang: [ on  ]
...                     libunwind: [ on  ]
...            libdw-dwarf-unwind: [ on  ]
...                          zlib: [ on  ]
...     DWARF post unwind library: libunwind
…
$ make LIBDW_DIR=/usr/local NO_LIBUNWIND=1 -C tools/perf
```