Debugging with GDB

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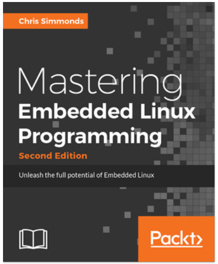
About Chris Simmonds



- Consultant and trainer
- Author of *Mastering Embedded Linux Programming*
- Working with embedded Linux since 1999
- Android since 2009
- Speaker at many conferences and workshops

"Looking after the Inner Penguin" blog at `http://2net.co.uk/`

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Objectives

- Show how to use GDB to debug applications
- How to attach to a running process
- How to look at core dumps
- Plus, we will look at graphical interfaces for GDB
- Reference: MELP2 Chapter 14

"Debugging is twice as hard as writing the code in the first place. Therefore, if you write the code as cleverly as possible, you are, by definition, not smart enough to debug it"
- Brian W. Kernighan

Native vs cross compiling

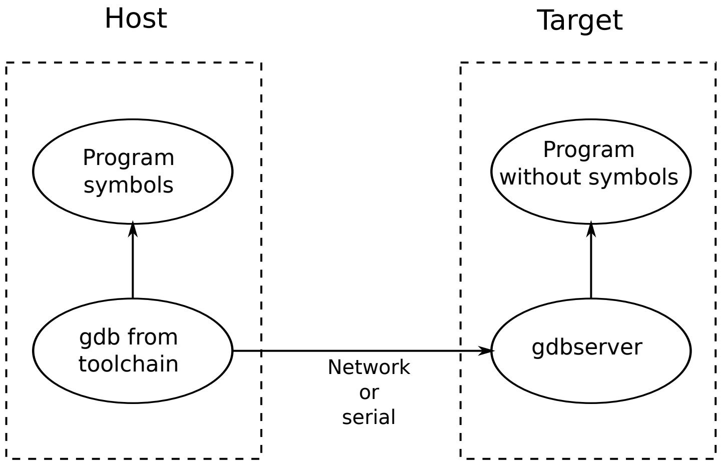
Native (on target)

- Makers, e.g. Raspberry Pi running Debian
- PC development

Cross (on host)

- Most embedded development
  - Better tools on dev host
  - Better integrated with SCM, etc

Remote debugging



Debug info

- Need debug info **on the host** for the applications and libraries you want to debug
  - It's OK for the files on the target to be stripped: gdbserver does not use debug info
- Compile with
  - **-g**: for source-level debugging
  - **-g3**: to include information about macros as well
- Debug info may be included in the binary (the Buildroot way)
- Or placed in a sub-directory named `.debug/` (the Yocto Project/OpenEmbedded way)

Code optimization

- Single-stepping through optimized code can be confusing
  - Bad: -O2 and -Os
  - Bearable: -O1
  - Good: -Og (debug-friendly opt) or -O0 (no opt)
- If you you experience problems, reduce the optimization level
- If back trace seems not to work, enable stack frames by adding to CFLAGS:
  - `-fno-omit-frame-pointer`

Setting sysroot

- **sysroot** tells GDB where to find library debug info
- For Buildroot

```
set sysroot <toolchain sysroot>
```

- Using a Yocto Project SDK:

```
set sysroot /opt/poky/<version>/sysroots/<architecture>
```

Command-line debugging

Development host

Embedded target

```
# gdbserver :2001 helloworld
```

```
$ arm-poky-linux-gnueabi-gdb helloworld
(gdb) set sysroot /opt/poky/2.5.1/...
(gdb) target remote 192.168.7.2:2001
```

```
“Remote debugging from host 192.168.7.1”
```

```
(gdb) break main
(gdb) continue
```

```
{program runs to main()}
```

Notes

- GDB command **target remote** links gdb to gdbserver
- Usually a TCP connection, but can be UDP or serial
- gbdserver loads the program into memory and halts at the first instruction
- You can't use commands such as **step** or **next** until after the start of C code at `main()`
- **break main** followed by **continue** stops at `main()`, from which point you can single step

GDB command files

- At start-up GDB reads commands from
  - `$HOME/.gdbinit`
  - `.gdbinit` in current directory
  - Files named by gdb command line option **-x [file name]**
- Note: auto-load safe-path
  - Recent versions of GDB ignore `.gdbinit` unless you enable it in `$HOME/.gdbinit`

```
add-auto-load-safe-path /home/myname/myproject/.gdbinit
```

Library code

- By default GDB searches for source code in
  - $cdir: the compile directory (which is encoded in the ELF header)
  - $cwd: the current working directory

```
(gdb) show dir
Source directories searched: $cdir:$cwdv
```

- You can extend the search path with the **directory** command:

```
(gdb) dir /home/chris/src/mylib
Source directories searched: /home/chris/src/mylib:$cdir:$cwd
```

Just-in-time debugging

- Both gdb and gdbserver can **attach** to a running process and debug it, you just need to know the PID
- With gdbserver, you attach like this (PID 999 is an example)

```
# gdbserver --attach :2001 999
```

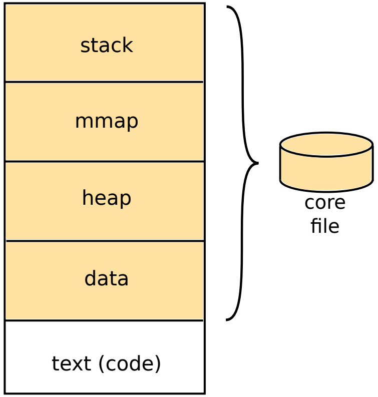
- If debugging natively using GDB, use the attach command:

```
(gdb) attach 999
```

- In either case, to detach and allow the process to run freely again:

```
(gdb) detach
```

Core dump



A core file is created if:

- size is < `RLIMIT_CORE`
- the program has write permissions to create a file
- not running with set-user-ID
- Set `RLIMIT_CORE` to un-limited using command: `ulimit -c unlimited`

Using gdb to analyse a core dump

- Command-line gdb

```
arm-poky-linux-gnueabi-gdb sort-debug ~/rootdir/usr/bin/core
...
Core was generated by `/sort-debug /etc/protocols'.
Program terminated with signal 11, Segmentation fault.
#0  0x00008570 in addtree (p=0x0, w=0xbeaf4c68 "Internet") at
sort-debug.c:45
45          p->word = strdup (w);
(gdb) back
#0  0x00008570 in addtree (p=0x0, w=0xbeaf4c68 "Internet") at
sort-debug.c:45
#1  0x00008764 in main (argc=2, argv=0xbeaf4e34) at sort-debug.c:95
(gdb)
```

Core pattern

- By default, core files are called `core` and placed in the working directory of the program
- If `/proc/sys/kernel/core_uses_pid` is non zero a dot and PID number are appended
- Or, core file names are constructed according to `/proc/sys/kernel/core_pattern`
- See man core(5) for details

Example: `/corefiles/%e-%p`

%e executable name
%p PID

Debug build - Yocto Project

- You need to add debug tools for the target: add this to your `conf/local.conf`

```
EXTRA_IMAGE_FEATURES = "debug-tweaks tools-debug"
```

- And you need to build an SDK which will contain the tools for the host, and the debug symbols

```
bitbake -c populate_sdk <image name>
```

Debug build - Buildroot

- You need to run menuconfig and enable these options

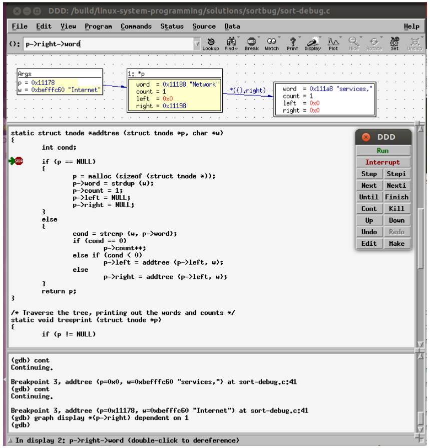
```
PACKAGE_HOST_GDB
PACKAGE_GDB
PACKAGE_GDB_SERVER
ENABLE_DEBUG
```

- Then re-build the image
- The executables with debug symbols are put in `output/host/usr/<arch>/sysroot`

GUI front ends

- There are many front-ends, including
  - TUI: Terminal User Interface
  - DDD: Data Display Debugger
  - Eclipse CDT
- As an example, the next two slides show how to use DDD

DDD: Data Display Debugger


DDD: /build/linux-system-programming/solutions/sortbug/sort-debug.c
File Edit View Program Commands Status Source Data Help
(): p->right->word
Lookup Find» Break Watch Print Display Plot Hide Rotate Set Undisp
Args
p = 0x11178
w = 0xbefffc60 "Internet"
1: *p
word = 0x11188 "Network"
count = 1
left = 0x0
right = 0x11198
*(().right)
word = 0x111a8 "services,"
count = 1
left = 0x0
right = 0x0
DDD
Run
Interrupt
Step Stepi
Next Nexti
Until Finish
Cont Kill
Up Down
Undo Redo
Edit Make

```
static struct tnode *addtree (struct tnode *p, char *w)
{
        int cond;

        if (p == NULL)
        {
                p = malloc (sizeof (struct tnode *));
                p->word = strdup (w);
                p->count = 1;
                p->left = NULL;
                p->right = NULL;
        }
        else
        {
                cond = strcmp (w, p->word);
                if (cond == 0)
                        p->count++;
                else if (cond < 0)
                        p->left = addtree (p->left, w);
                else
                        p->right = addtree (p->left, w);
        }
        return p;
}

/* Traverse the tree, printing out the words and counts */
static void treeprint (struct tnode *p)
{
        if (p != NULL)
```

```
(gdb) cont
Continuing.

Breakpoint 3, addtree (p=0x0, w=0xbefffc60 "services,") at sort-debug.c:41
(gdb) cont
Continuing.

Breakpoint 3, addtree (p=0x11178, w=0xbefffc60 "Internet") at sort-debug.c:41
(gdb) graph display *(p->right) dependent on 1
(gdb)
```

In display 2: p->right->word (double-click to dereference)

Starting DDD

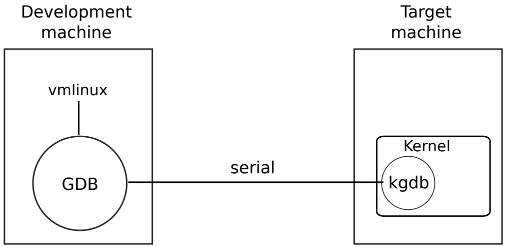
- `--debugger [GDB to use]`
- `-x [GDB command file]`
- Example:

```
$ ddd --debugger arm-poky-linux-gnueabi-gdb -x ~/gdbcmd [program]
```

Debugging kernel code

Outside the scope of this workshop, but ...

- Build kernel with KGDB - which is like gdbserver but integrated into the kernel
- Connect to serial port on target
- Read debug symbols from vmlinux file



Lab time...

Get the slides and sample code from

`https://cm.e-ale.org/2018/debugging-ELCE-2018-csimmonds`

Follow the notes in
debugging-EALE-2018-csimmonds-workbook.pdf

Call me or one of the helpers if you encounter problems

Delving deeper

- This is an excerpt from my **Fast track to embedded Linux** class
- If you would like to discover more about the power of embedded Linux, visit `http://www.2net.co.uk/training.html` and enquire about training classes for your company
    - 2net training is available world-wide
- Also, my book, *Mastering Embedded Linux Programming*, covers the topics discused here in much greater detail