



DORNERWORKS

Debugging seL4 Applications with GDB

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- Debugging Need for Embedded Systems
- GDB Overview
- 3 Implementations
 - GDB-stub ARM – DW
 - GDB-server x86 – Data61
 - GDB-server ARM – DW
- Areas for Improvement
- Questions



Summary

About DornerWorks

Embedded Systems Engineering located in Grand Rapids, MI

DornerWorks provides technology engineering so you can focus on your customers.

- Embedded electronics
- FPGA
- Software engineering
- Cloud ad mobile apps

We accelerate your product development and lower risk for adopting advanced technologies.

Experience with seL4

DARPA SBIR Project: “An seL4 – Enabled Safe & Secure Soldier Helmet Display”



Why Debuggers?

- No matter the length and readability of your code, there is **always** the possibility for bugs
 - Print debugging is inflexible
 - UART access may be limited when porting to a new platform
- Doesn't work well with timing-sensitive functions or interrupt handlers
- Debug functions allow for easier error identification

About GDB

- GNU Project Debugger, Developed in 1986 by Richard Stallman
- Most widely used embedded debugger
- Allows the user to see what happens 'inside' the program while it is executing
- Available Functionality:
 - Breakpoints
 - Step-Through
 - Variables
 - Stack
 - Many, Many others...
- How can this be implemented in seL4?

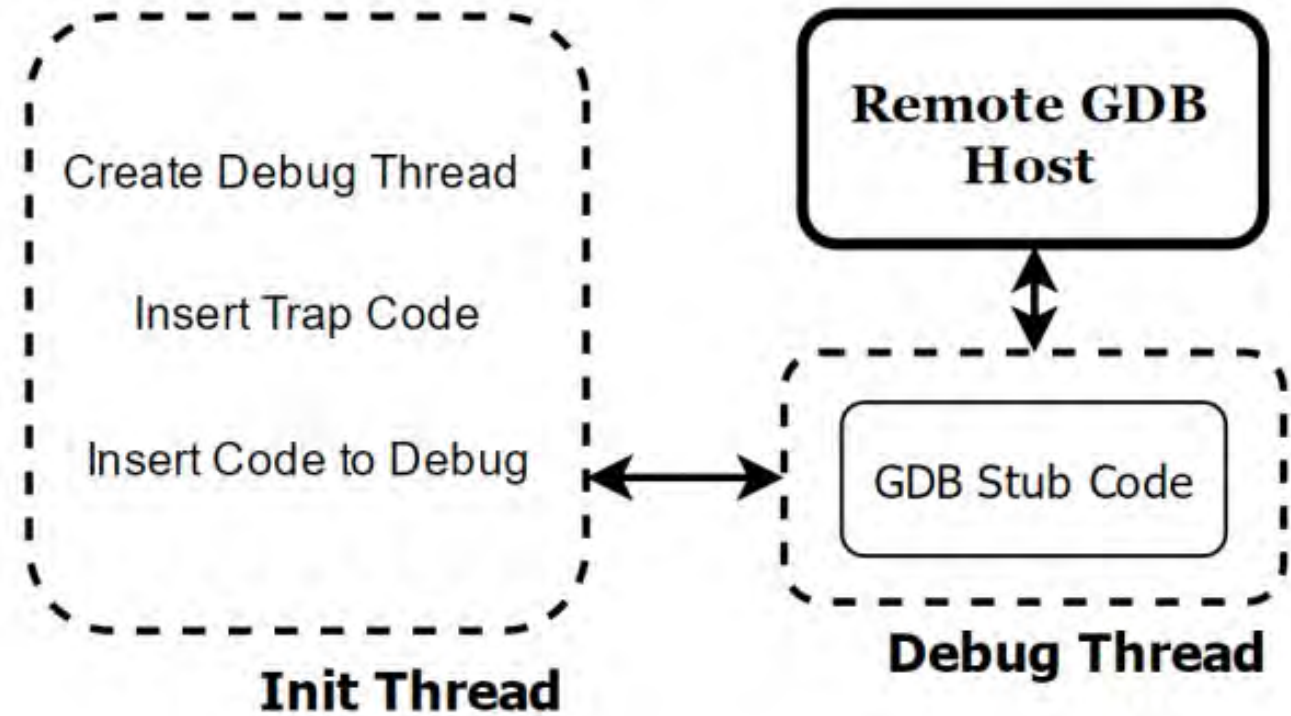
Overview of seL4 GDB Solutions

- GDB Stub Application
 - gdbstub: Code must be linked directly with the application to debug with GDB
 - For programs written with seL4 System Calls
 - Not for CAmkES applications
- GDB Server Applications
 - gdbserver: control program which allows you to connect your program with gdb without linking in the usual debugging stub.
 - CAmkES application for x86 (Data61) and ARM (DW)

GDB stub

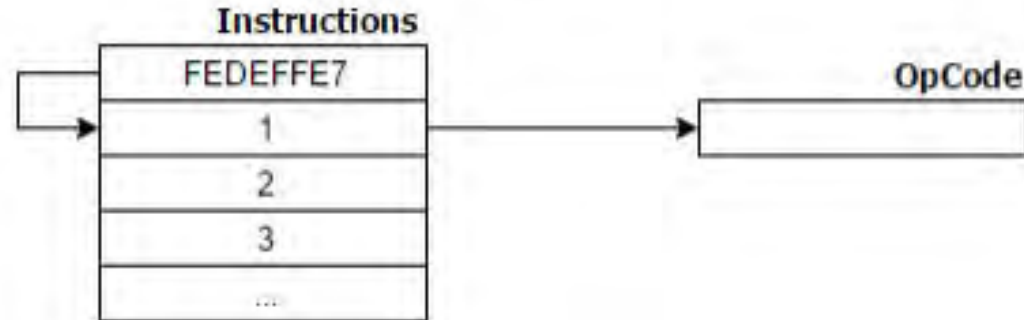
- Developed by DornerWorks
- Only tested on Zynq7000 Platform
 - Other ARM Platforms should work
- <https://github.com/dornerworks/gdbstub-app>
- <https://github.com/dornerworks/gdbstub-appmanifest>

GDB stub



GDB stub

- GDB Stub communicates with the GDB application over UART0
 - Normal Serial Communication occurs over UART1
- Wait for user commands
 - Software Breakpoints
 - Read/Write bytes
 - Step
 - Continue
- Step/continue resumes init thread with updated PC



GDB stub

- Strengths:
 - Can debug seL4 code!
- Weaknesses
 - Hard Coded Stub
 - No CAmkES support
 - Uses init thread to debug code

GDB Stub

Strengths

- Can debug seL4 code!

Weaknesses

- Hard Coded Stub
- No CAmkES support
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x86 GDB for CAmkES

X86 GDB for CAmkES

- Developed by Data61
- https://github.com/smaccm/camkes_debug_manifest/blob/gtt_deliverable/simple.xml
- https://github.com/smaccm/camkes-tool/blob/gtt_deliverable_debug_no_rt/debug/README.md

X86 GDB for CAmkES

- Debug tool performs the following:
 - Parses the top level assembly file & outputs new assembly file
 - Creates a delegate and a fault endpoint from template files
 - Outputs a .gdbinit

X86 GDB for CAmkES

- Available commands:
 - Read general registers
 - Memory read/write
 - Set SW breakpoint
 - Set HW breakpoint
 - Step

X86 GDB for CAmkES

Strengths

- GDB Server
- HW/SW Breakpoints
- CAmkES compatible

Weaknesses

- No ARM support

ARM GDB for CAmkES

Strengths

- GDB Server
- Improved SW Breakpoints
- ✕ ARM/CAmkES compatible

Weaknesses

- Cannot debug multiple threads at once

Where Do We Go From Here?

- Multi-Thread capable GDB Server
- HW breakpoints for ARM
- “Detach” operation
- Communicate through Ethernet
- Refactor ARM/x86 applications to be similar
 - Build one application based off the required platform
- Integrate GDB Server to a seL4 IDE
 - Once a seL4 IDE is developed!



ARM GDB for CAmkES

ARM GDB for CAmkES

- Based off the Data61 GDB Server
- Developed by DornerWorks
- Modified in the following ways:
 - ARM Support
 - Additional GDB functionality

ARM GDB for CAmkES

- Debug tool slightly modified
 - Searches for the source file of the debug component, adds a breakpoint() function call
 - Creates a backup of the source code
- Creates a new target file (.camkes.dbg)
- Creates a .gdbinit file

ARM GDB for CAmkES

```
assembly {  
  composition {  
    component Sender1 sender1;  
    component Receiver1 receiver1;  
    connection seL4RPC conn1(from sender1.out1, to receiver1.in1);  
  }  
  configuration {  
    receiver1.debug = "False";  
    sender1.debug = "True";  
  }  
}
```

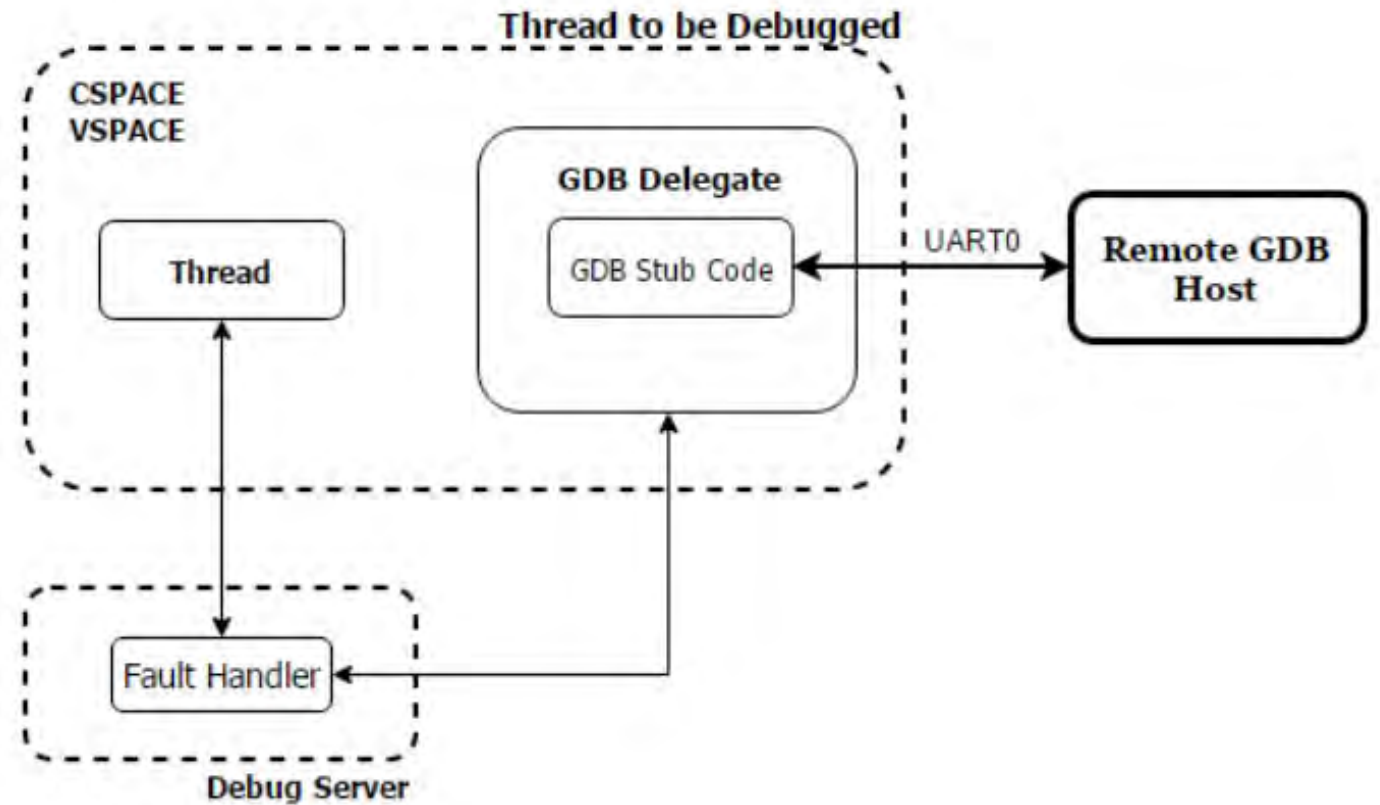
```
assembly {  
  composition {  
    component debug_server debug;  
    component debug_Serial debug_hw_serial;  
    component Sender1 sender1;  
    component Receiver1 receiver1;  
    connection seL4HardwareMMIO uart_mem (from debug.mem, to debug_hw_serial.mem);  
    connection seL4Debug debug0_delegate (from debug.sender1_GDB_delegate, to sender1.GDB_delegate);  
    connection seL4GDB debug0 (from sender1.fault, to debug.sender1_fault);  
    connection seL4HardwareMMIO uart_mem0 (from sender1.mem, to debug_hw_serial.mem);  
    connection seL4RPC conn1 (from sender1.out1, to receiver1.in1);  
  }  
  configuration {  
    receiver1.debug = "False";  
    sender1.debug = "True";  
    debug_hw_serial.mem_attributes = "0xe0000000:0x1000";  
  }  
}
```

ARM GDB for CAmkES

```
component Sender1 {  
    control;  
    uses MyInterface out1;  
}
```

```
component Sender1 {  
    control;  
    provides CAmkES_Debug GDB_delegate;  
    uses MyInterface out1;  
    uses CAmkES_Debug fault;  
    dataport Buf mem;  
}
```

ARM GDB for CAmkES



ARM GDB for CAmkES


- Fault Endpoint
 - Component generated by debug tool
 - Linked to template files
 - EP is generated by the python script & templates
 - Connected to the fault EP of the debugged thread
 - Fault handler waits for something to occur on the EP
 - Gets the TCB Capability so GDB can read registers, manipulate the instructions, etc...

ARM GDB for CAmkES

- Delegate:
 - Component generated by the debug tool
 - Linked to template files
 - “Provided” by the debugged component.
 - Runs in same vspace/cspace
 - Capability to vspace – allows for instruction modification
 - Required for SW Breakpoints
 - Activated when called from the Fault Endpoint
 - Has a slightly modified version of the stub application for GDB functionality

ARM GDB for CAmkES

- Available commands:
 - Read/Write general registers
 - Memory read/write
 - Set/Remove SW breakpoint
 - Step/Continue
 - Kill



DornerWorks, Ltd.

Thank You

📞 +1.616.245.8369

✉ sales@dornerworks.com

🌐 <https://dornerworks.com/>