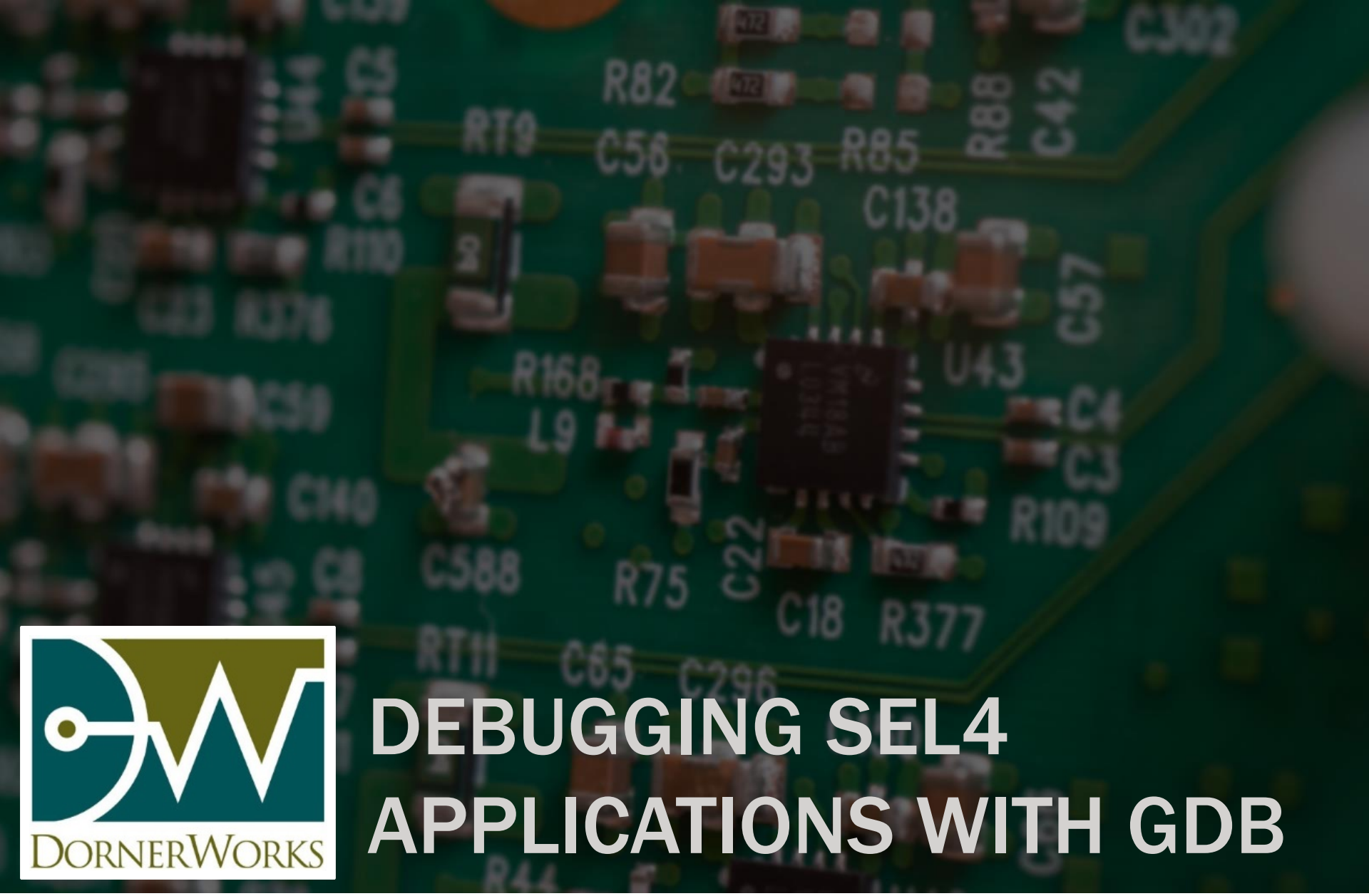

DEBUGGING SEL4 APPLICATIONS WITH GDB

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Agenda

- 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

About DornerWorks

- Embedded Systems Engineering located in Grand Rapids, MI
- DornerWorks provides expert technology engineering to help product developers create standout products so that they are free to focus on what they do best.
- We specialize in platforms
  - Hardware development
  - Software and firmware designs
  - FPGA logic designs
- 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?

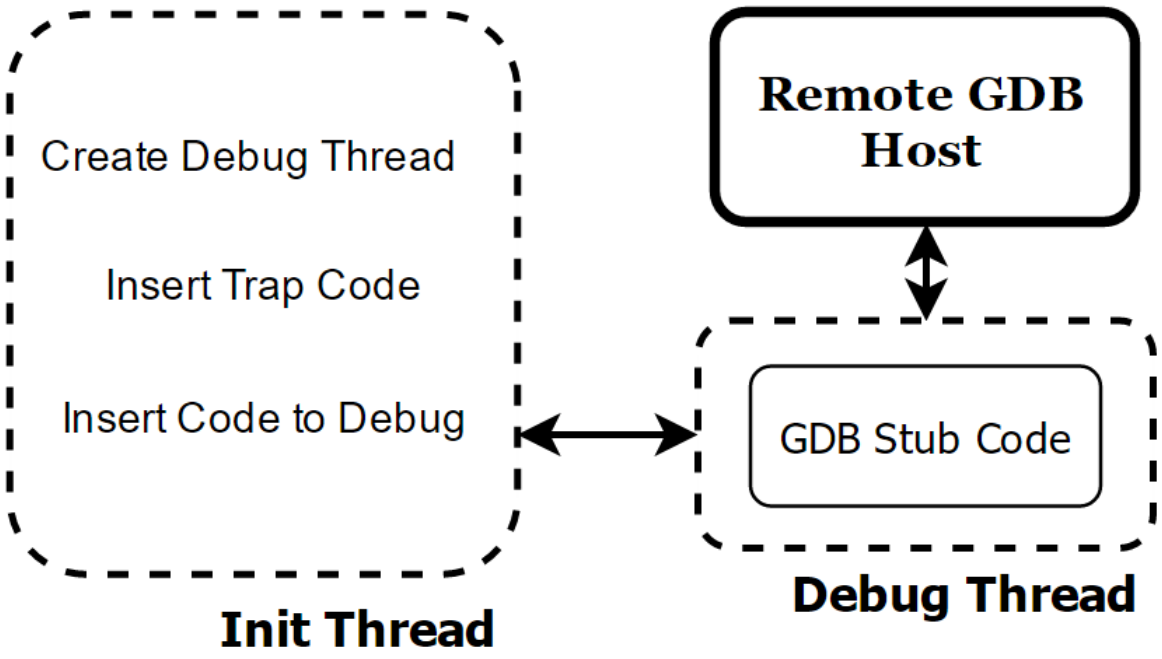
Overview of seL4 GDB Solutions

- 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

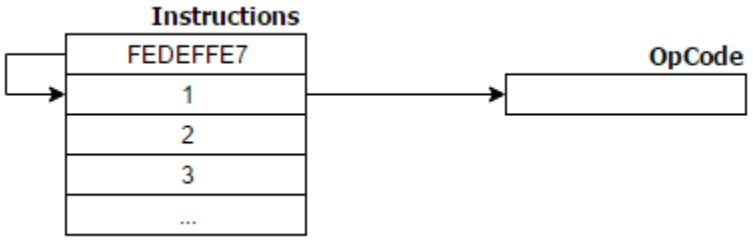
- Developed by DornerWorks
- Only tested on Zynq7000 Platform
  - Other ARM Platforms should work
- https://github.com/dornerworks/gdbstub-app
- https://github.com/dornerworks/gdbstub-app-manifest

GDB Stub


Create Debug Thread
Insert Trap Code
Insert Code to Debug
Init Thread
Remote GDB Host
GDB Stub Code
Debug Thread

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

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 does 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

- 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";
  }
}
```

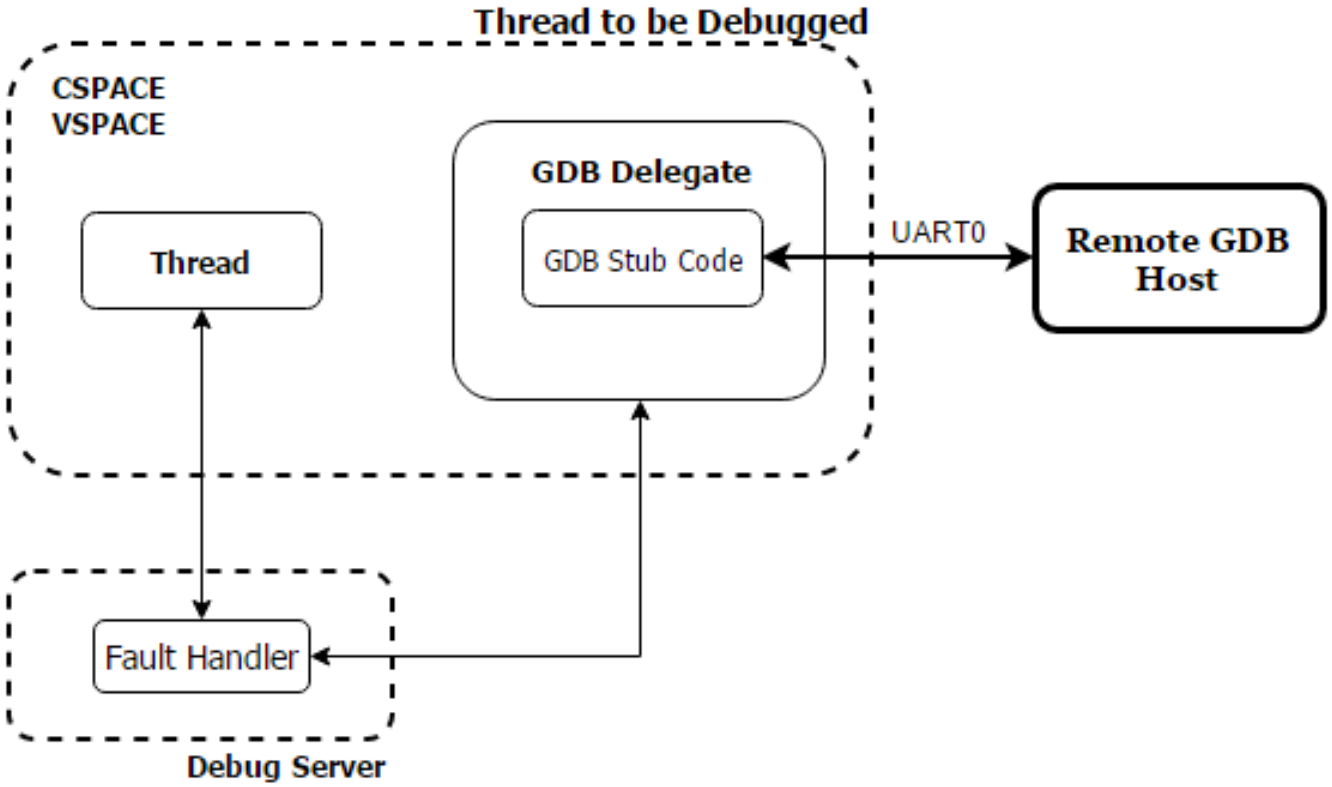
```
assembly {
  composition {
    component debug_server debug;
    component debug_Serial debug_hw_serial;
    component Sender1 sender1;
    component Receiver1 receiver1;
    connection seL4HardwareMMIO uart_mem (from debug.mem, to debug_hw_serial.mem);
    connection seL4Debug debug0_delegate (from 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

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!

Questions??